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FOREWORD

IN THIS monograph are presented twelve studies conducted by graduate students and faculty of the State University of Iowa. With the exception of the papers by Travis, Tuttle, and McCloy, these represent condensations of graduate theses, which in their original form are filed in the library of the University.

These studies were conducted in the laboratories of the Departments of Physiology and Hygiene in the College of Medicine, and in the Division of Physical Education in the College of Liberal Arts.

It will be seen that these studies present research findings in a number of different subjects and employ a large number of different kinds of research techniques. Some present studies of a relatively pure science nature, while others are very practical applications of simple techniques to immediately useful and significant problems. Only two of these studies, those by Dr. Rooks and Dr. Lapp, are doctoral dissertations (condensed).

The studies by Vogel, Lapp (1), and White were directed by Professor W. W. Tuttle. The study by Rooks was directed by Dr. A. V. Hardy of the Department of Hygiene of the College of Medicine. Those by Waggoner, Cameron, Sterrett, Roggen, Flanagan, Wendler, Emma McCloy, and Lapp (2) were directed by Professor C. H. McCloy. The others represent independent studies by members of the faculty.

C. H. MCCLOY.

The Relation of Precedence of Movement in Homologous Structures to Handedness

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Department of Physiology
and LEE EDWARD TRAVIS,
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State University of Iowa

WHEN manual acts are performed, lead preference is usually given to one side of the body. There is good evidence that sidedness is an inherited characteristic. There is equally good evidence that it is subject to social conditioning. The problem of heredity versus environment is the same here as it is in other fields. Furthermore, the end results promise to be the same, namely a compromise between opposing forces. It is clear that certain acts involving unilateral preference or a one-sided lead are more subject to environmental influence than are others. We selected for study a type of movement which was not greatly influenced by social pressure. We were interested primarily in what might be termed native or inherent unilateral organization and how such organization may be related to ordinary expressions of unilateral choice and to acts of skill in athletic activities. This latter problem is treated by Vogel [1]* in a preliminary way in another paper of this series.

Three previous studies are particularly pertinent to the present research. Orton and Travis[2] found that during the simultaneous flexion of the digits of the two hands, action currents tended to arrive first in the right forearm of the majority of right-handed normal speakers. Travis and Herren,[3] in a study of simultaneous antitropic movements of the two hands (abduction and adduction), found that right-handed subjects lead more frequently with the left hand while left-handed subjects lead more frequently with the right hand. Metfessel and Warren,[4] in having the subjects attempt simultaneous movements of the first two fingers of each hand, found a tendency for both action current and movement leads to favor the hand not used in writing. All of these reports involved a study of stutterers, which need not concern us here.

The results reported by Orton and Travis[2] disagree with those reported by the other workers in regard to the lead preferences, as deter-

* Numbers refer to bibliography at end of article.

mined in the experiments, compared to handedness. In analyzing the findings of these three studies, it appears that the instructions given to the subjects and the tasks involved determined, to a large measure, the lead preferences manifested by the observers. Orton and Travis[2] requested their subjects to close both hands in response to the appearance of the noise made by the turning of a photographic camera. This noise was slight and the subject was obliged to pay attention in order to detect its appearance. The task (closing the hands) was so simple that it should not have required much, if any, attention on the part of the subject to execute. Travis and Herren[3] instructed their subjects to move the hands at the command "Go." The task was rather complicated, requiring the subject to grasp two styli and move them outward or inward in a precise and smoothly controlled movement against smoked paper revolved by a kymograph drum. Here, there is every reason to suspect that the attention of the subject was directed to the movements and not to the stimulus, inasmuch as the response was the much more complicated of the two. Metfessel and Warren[4] instructed their subjects to press both keys *simultaneously* (italics ours) with each flash of a light. The task consisted of breaking a circuit requiring 290 grams pressure for the right and 295 grams pressure for the left forefinger. Here again it is conceivable that the attention of the subject was directed more to the response than to the stimulus, since the response would require some effort and the instructions were to move the fingers simultaneously.

If our conclusions in regard to the instructions and tasks involved in these three experiments are correct, the latter two studies gave the subjects a mental set conducive to over-compensation by the non-preferred hand. The subject, in concentrating on the movements, paid more attention to the non-preferred than to the preferred hand, with the result that he tended to lead more frequently with the former than with the latter. To test these deductions the present experiment was undertaken.

APPARATUS AND TECHNIQUE

For the purpose of comparing the movements of the two sides of the body, flexion of the forearms was employed. This required the development of a stimulus unit, a response unit, and a recording and timing device.

The Response Unit.—The response unit consisted of two telegraph keys, each in a separate circuit, in series with a signal magnet and two dry cells. The keys were mounted on an elevated base with a hand rest as shown in Fig. 1, and arranged in circuits as shown in Fig. 2. The signal magnets were supported in front of the aperture of a recording camera in such proximity to it that the styli extended completely across the aperture. The equipment was tested before each experiment in order to make sure that both keys and signal magnets were capable of responding simul-

taneously. The signal magnets were checked by placing them in the same circuit and recording their response to a single key. The keys were tested by adjusting the springs so that it required one kilogram of weight to close each of them.

The subject was comfortably seated at a table with the elbows resting on a pad. The back of the forearms rested on the keys and the back of the hands on the hand supports. The lateral distance between the keys was adjusted for each subject. The arms were kept in the position just described in a state of relaxation.

The Stimulus Unit.—The stimulus unit consisted of a bank of lamps

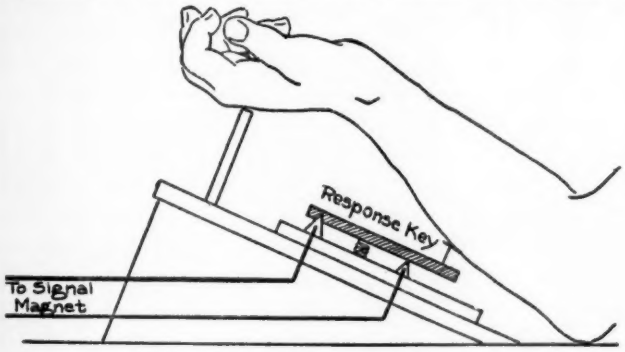

FIG. 1.—The arm in position on the response key.

wired as shown in Fig. 2, which was placed on a table in front of the subject. The lamps used were three- to five-volt radio pilot lights. Key 1 closed the circuit of light 1, key 2 that of light 2, and so on as indicated in Fig. 2.

The Recording Device.—The recording apparatus, as shown in Fig. 2, was placed in a room adjoining the stimulating and response units. It consisted of a recording camera employed as standard equipment for photographing electrocardiograms. In order to adapt this camera to our problem it was necessary to increase the speed to 120 R.P.M. Since 35 mm. recording paper was employed, it was necessary to place a steel guide on the shaft of the camera magazine so that the narrow paper was pulled straight behind the lens. A standard arc lamp was used as a source of light.

The Timing Device.—The timing device was a modification of the synchronous motor time recorder used for electrocardiography. A wheel with 20 spokes was substituted for the one with 5 spokes. The twentieth spoke was omitted. Since the motor was driven by a standard 50 d.v. electric vibrating bar, each spoke cut the beam of light 5 times per second, thus setting off intervals of 1/100 sec. The omitted spoke divided the record in groups of 20/100 sec.

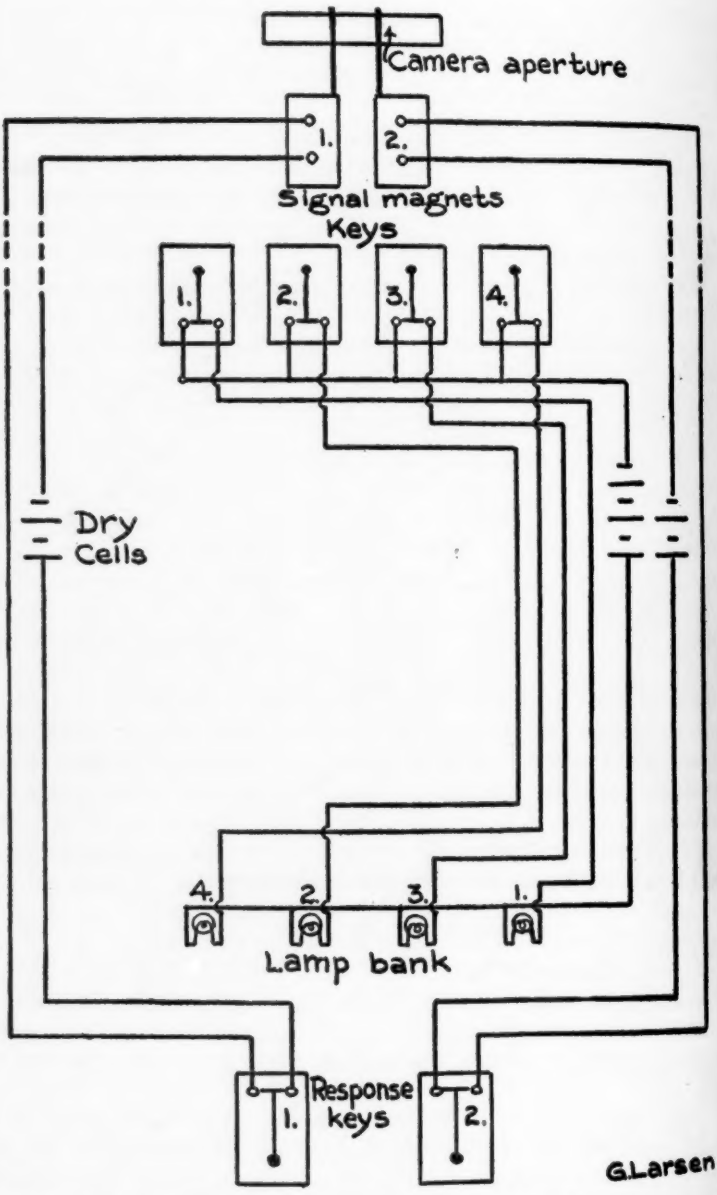

FIG. 2.—The arrangement of the apparatus for giving the stimulus pattern and recording the response.

Making the Record.—When the subject was adjusted to the response unit, the experimenter took his position at the signal keys and his assistant made ready to operate the recording camera. When the experimenter gave the signal, the camera was opened and the responses recorded. The recording paper was collected, developed, and fixed in the usual manner.

Three sample records are shown in Fig. 3. The line (x) is a shadow of the galvanometer string but has nothing to do with this experiment.

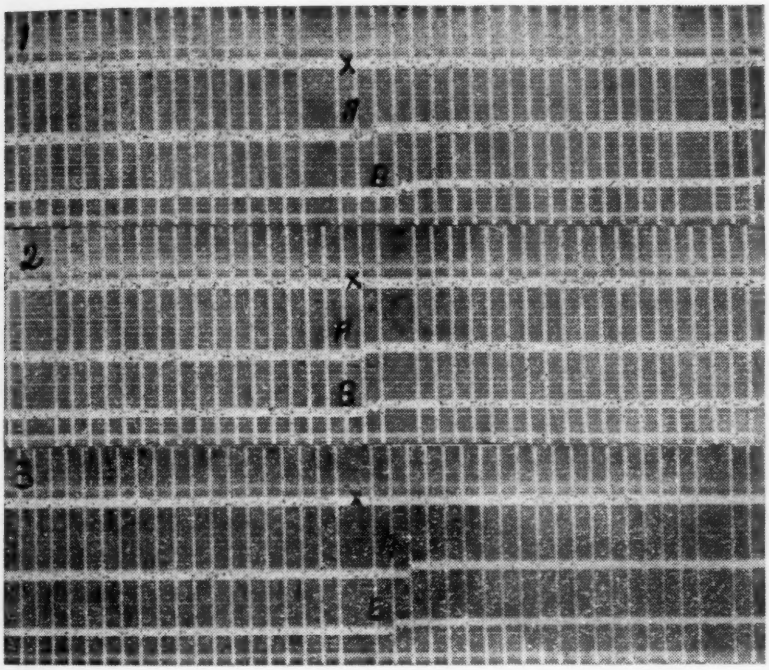

FIG. 3.—Records showing (1) right lead, (2) simultaneous lead, and (3) left lead.

(A) is the response of the right arm as shown by a break in the shadow. (B) is the response of the left arm. The vertical shadows are time lines. Record 1 shows a right lead of .013 sec.; in record 2 the responses were simultaneous; and in record 3 the left arm led by .010 sec. In each experiment from 7 to 16 records were made.

A lead is considered as right or left when the breaks in the shadows made by the response keys are far enough apart to be unmistakably recognized.

Situations.—In order to test the influence of instructions and the task involved upon the lead preferences, we set up three experimental situations as follows:

Situation 1. The subject was requested to raise the forearms upon the appearance of a light flash of a single lamp. He was instructed to watch for the flash and to elevate both forearms upon perceiving it. Nothing was said about moving the arms simultaneously. Here both the stimulus and the movement were very simple. Nothing was either said or implied to direct the subject's attention more to the stimulus than to the response, or vice versa. He was left free to direct his attention as he chose.

Situation 2. The procedure was the same as that for situation 1, except strong emphasis was placed upon the subject's raising the forearms *simultaneously*. He was instructed to concentrate on every single set of movements in order that he might raise the two forearms at the same time. The purpose here was to see if the subject would consciously or unconsciously direct his attention to the non-preferred arm in order that he would be sure to elevate it as quickly as he did the preferred arm, which might conceivably more or less take care of itself.

Situation 3. Here an attempt was made to direct the attention of the subject completely to the stimulus in order that the movements might be as free from attentional control as possible. The subject was instructed to raise the arms at the flash of a given lamp, only when this flash was preceded by the flash of three other lights in a certain order. Right and wrong sequences were presented indiscriminately, the subject never knowing when the proper sequence was to occur. Since all subjects made many false responses, it appeared that the stimulus pattern was of sufficient complexity to demand the undivided attention of the subject.

THE SELECTION OF SUBJECTS

On the basis of a laterality index,[5] three groups of subjects were selected: a right-handed, a left-handed, and an ambidextrous group. The laterality index was computed from a list of 33 performances which the subject was asked to check as to whether he did them either with the right hand, the left hand, both hands, or either hand. An individual's laterality index score was determined by the formula $\frac{R + \frac{1}{2}E}{N} \times 100$, where R equals the number of right-handed responses, E the number of responses involving no choice for either hand, and N the total number of performances checked. A score between 97 and 100 inclusive indicated right-handedness; between 0 and 35 inclusive, left-handedness; and between 36 and 96 inclusive, ambidexterity. There were 25 right-handed, 21 left-handed, and 11 ambidextrous subjects. All subjects were adults and the great majority of them were male.

DATA AND DISCUSSION

Three-hundred-fifteen records were obtained from the right-handed group in each situation. In situation 1, 45 per cent of the responses were

right leads, 49 per cent were left, and 6 per cent were simultaneous. In situation 2, 42 per cent of the responses were right leads, 53 per cent were left, and 5 per cent were simultaneous. For situation 3, 58 per cent of the responses were right leads, 40 per cent were left, and 2 per cent were simultaneous.

Two hundred sixty-four records were obtained from the left-handed group in each situation. In situation 1, 35 per cent of the responses were right leads, 63 per cent were left, and 2 per cent were simultaneous. In situation 2, 51 per cent of the responses were right leads, 48 per cent were left, and 1 per cent was simultaneous. In situation 3, 15 per cent of the responses were right leads, 84 per cent were left, and 1 per cent was simultaneous.

One hundred forty records were obtained from the ambidextrous group in each situation. In situation 1, 53 per cent of the responses were right leads, 41 per cent were left, and 6 per cent were simultaneous. In situation 2, 50 per cent of the responses were right leads, 37 per cent were left, and 13 per cent were simultaneous. In situation 3, 62 per cent of the responses were right leads, 34 per cent were left, and 4 per cent were simultaneous.

It may be noted that none of the situations is adequate for measuring right sidedness as determined by the laterality index. For the left-handed group, situation 1 and situation 3 gave a significantly greater percentage of left leads.

A detailed examination of the data (Table I) shows that there are a number of subjects who, on the basis of all three situations, do not belong in the group to which they are assigned by the laterality index. For example, subjects (Table I) 4, 5, 10, 17, 25, 33, 41, 44, 49, 53, and 56 were not right-handed according to the experimental situations. Further, subjects (Table III) 6 and 15 were not ambidextrous according to the experimental situations. When those subjects who gave conflicting results were removed from the tables, the percentage distribution of leads was as follows:

	Situation 1 per cent	Situation 2 per cent	Situation 3 per cent
The Experimentally Right Dominant Group			
R	75	66	96
L	21	30	4
S	4	4	1
The Experimentally Left Dominant Group			
R	29	47	5
L	69	52	94
S	2	1	1
The Experimentally Ambidextrous Group			
R	47	48	55
L	47	37	39
S	6	15	6

An examination of these data will show that the results obtained in situation 1 are comparable with those found by Orton and Travis. Although there is not as complete a reversal in situation 2 as that found by Travis and Herren, and by Metfessel and Warren, the tendency is decidedly in that direction. In situation 3 we have the clearest differentiation of the three groups. The great majority of the responses for the left-handed group are left leads, with the ambidextrous group showing some favoritism for right leads.

The influence which the various stimulus patterns had on the results is clearly shown in certain cases. In situation 2 there was a complete reversal of lead preference for subjects 6 and 32. Subjects 4, 13, 17, 18, 21, 24, 27, 28, 34, and 44 became ambidextrous in this situation. Further evidence that the situations affected the results is shown by the following mean differences between the responses of the two sides (Tables IV, V, and VI):

Group	*Situation 1*	*Situation 2*	*Situation 3*
Right dominant	.0118 sec.	.0087 sec.	.0146 sec.
Left dominant	.0112 sec.	.0129 sec.	.0215 sec.
Ambidextrous	.0105 sec.	.0125 sec.	.0109 sec.

From this it is evident that for the right and left experimentally dominant groups the lapsed time between the right and left responses is greatest in situation 3. It is noteworthy that for all situations, except the right dominant, situation 2, the ambidextrous group has the shortest elapsed time between the responses of the two sides.

It might be concluded that the precedence of lead in simultaneous contraction of homologous muscle groups is determined largely by the instructions given and the tasks involved. When the stimulus pattern to which the subjects respond is relatively complicated, the lead preferences are more strictly in harmony with the handedness of the subjects as indicated by ordinary manual activities of everyday life.

TABLE I

A Summary of the Data Collected from the Right-Handed Group Classified on the Basis of the Laterality Index

Sub. No.	Laterality Index	No. right responses / Per cent right responses			No. left responses / Per cent left responses			No. simultaneous responses / Per cent simultaneous responses		
		Situation			Situation			Situation		
		1	2	3	1	2	3	1	2	3
2	100	10 100	9 90	10 100	0 0	0 0	0 0	0 0	1 10	0 0
3	100	8 100	6 75	8 100	0 0	1 12	0 0	0 0	1 12	0 0
4	97	8 7	0 0	0 0	12 86	14 100	14 100	1 7	0 0	0 0

TABLE I (*Continued*)

Sub. No.	Laterality Index	No. right responses / Per cent right responses			No. left responses / Per cent left responses			No. simultaneous responses / Per cent simultaneous responses		
		Situation			Situation			Situation		
		1	2	3	1	2	3	1	2	3
5	100	0 / 0	0 / 0	0 / 0	9 / 90	10 / 100	10 / 100	1 / 10	0 / 0	0 / 0
8	100	15 / 94	12 / 75	15 / 94	1 / 6	3 / 19	1 / 6	0 / 0	1 / 6	0 / 0
10	97	5 / 33	4 / 27	2 / 13	8 / 53	10 / 67	12 / 80	2 / 13	1 / 7	1 / 7
17	99	0 / 0	5 / 31	0 / 0	15 / 94	11 / 69	14 / 88	1 / 6	0 / 0	2 / 12
18	97	10 / 100	10 / 100	10 / 100	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
25	100	2 / 17	6 / 50	6 / 50	9 / 75	4 / 33	4 / 33	1 / 8	2 / 17	2 / 17
26	100	2 / 17	8 / 67	10 / 83	10 / 83	4 / 33	2 / 17	0 / 0	0 / 0	0 / 0
31	97	13 / 86	13 / 86	15 / 100	0 / 0	1 / 7	0 / 0	2 / 14	1 / 7	0 / 0
33	100	2 / 15	2 / 15	3 / 23	10 / 77	9 / 70	9 / 70	1 / 7	2 / 15	1 / 7
34	100	9 / 90	6 / 60	10 / 100	1 / 10	4 / 40	0 / 0	0 / 0	0 / 0	0 / 0
35	100	10 / 83	12 / 100	12 / 100	1 / 8	0 / 0	0 / 0	1 / 8	0 / 0	0 / 0
36	100	2 / 25	3 / 38	8 / 100	6 / 75	4 / 50	0 / 0	0 / 0	1 / 12	0 / 0
39	97	5 / 38	0 / 0	13 / 100	6 / 46	13 / 100	0 / 0	2 / 16	0 / 0	0 / 0
40	100	6 / 67	2 / 22	9 / 100	3 / 33	6 / 67	0 / 0	0 / 0	1 / 11	0 / 0
41	97	2 / 13	1 / 7	4 / 27	13 / 87	14 / 93	9 / 60	0 / 0	0 / 0	2 / 13
42	100	12 / 92	12 / 92	13 / 100	1 / 8	1 / 8	0 / 0	0 / 0	0 / 0	0 / 0
43	100	10 / 71	8 / 57	12 / 86	2 / 14	5 / 35	1 / 7	2 / 14	1 / 8	1 / 7
44	100	2 / 13	3 / 20	0 / 0	12 / 80	11 / 73	15 / 100	1 / 7	1 / 7	0 / 0
49	100	5 / 31	2 / 12	4 / 25	8 / 50	14 / 87	12 / 75	3 / 19	0 / 0	0 / 0
50	100	11 / 79	7 / 50	12 / 86	3 / 21	7 / 50	2 / 14	0 / 0	0 / 0	0 / 0
53	97	1 / 10	1 / 10	1 / 10	8 / 80	8 / 80	9 / 90	1 / 10	1 / 10	0 / 0
56	98	0 / 0	0 / 0	4 / 27	15 / 100	15 / 100	11 / 73	0 / 0	0 / 0	0 / 0
Sum		143	132	181	153	169	125	19	14	9
Per cent		45	42	58	49	53	40	6	5	2

Total responses for each situation, 315

TABLE II

A Summary of the Data Collected from the Left-Handed Group Classified on the Basis of the Laterality Index

Sub. No.	Laterality Index	No. right responses / Per cent right responses			No. left responses / Per cent left responses			No. simultaneous responses / Per cent simultaneous responses		
		Situation			Situation			Situation		
		1	2	3	1	2	3	1	2	3
		2	11	1	8	1	11	2	0	0
1	6	16	92	8	67	8	92	16	0	0
		0	0	0	16	16	16	0	0	0
12	7	0	0	0	100	100	100	0	0	0
		1	4	6	14	11	15	0	0	0
13	34	7	27	0	93	73	100	0	0	0
		5	5	2	5	6	9	1	0	0
14	30	45	45	18	45	55	82	10	0	0
		3	4	0	10	9	13	0	0	0
20	36	23	30	0	77	70	100	0	0	0
		4	14	2	12	2	14	0	0	0
23	30	25	87	13	75	13	87	0	0	0
		2	9	2	10	2	10	0	1	0
28	30	17	75	17	83	17	83	0	8	0
		8	9	1	3	2	9	0	0	1
29	15	73	82	9	27	18	82	0	0	9
		0	0	0	8	8	8	0	0	0
30	8	0	0	0	100	100	100	0	0	0
		0	15	0	15	0	15	0	0	0
32	3	0	100	0	100	0	100	0	0	0
		6	6	4	5	5	6	0	0	1
37	19	55	55	36	45	45	55	0	0	0
		1	0	0	11	12	12	0	0	0
38	10	8	0	0	92	100	100	0	0	0
		2	13	0	9	0	13	2	0	0
45	5	15	100	0	70	70	100	15	0	0
		7	11	11	6	2	2	0	0	0
46	15	54	84	84	46	16	16	0	0	0
		5	10	8	5	1	3	1	0	0
47	25	45	91	73	45	9	27	9	0	0
		13	8	7	1	5	7	0	1	0
48	35	93	57	50	7	36	50	0	7	0
		8	11	0	3	0	11	0	0	0
51	0	73	100	0	27	0	100	0	0	0
		12	4	0	0	6	12	0	2	0
52	10	100	33	0	0	50	100	0	17	0
		7	1	0	4	10	11	0	0	0
54	13	67	9	0	36	91	100	0	0	0
		6	0	1	10	16	15	0	0	0
55	15	38	0	6	62	100	94	0	0	0
		1	0	2	10	11	9	0	0	0
57	5	9	0	19	91	100	81	0	0	0
Sum		93	135	41	165	125	221	6	4	2
Per cent		35	51	15	63	48	84	21	1	1

Total responses for each situation, 264

TABLE III

A Summary of the Data Collected from the Ambidextrous Group Classified on the Basis of the Laterality Index

Sub. No.	Laterality Index	No. right responses / Per cent right responses			No. left responses / Per cent left responses			No. simultaneous responses / Per cent simultaneous responses		
		Situation			Situation			Situation		
		1	2	3	1	2	3	1	2	3
		9	2	10	1	9	1	1	0	0
6	87	82	19	90	9	81	9	9	0	0
		4	6	0	7	5	11	1	1	1
7	92	33	49	0	58	41	92	8	8	8
		5	6	7	10	6	5	0	3	3
9	95	33	40	47	67	40	33	0	20	20
		7	14	12	4	1	2	4	0	1
11	94	47	93	80	27	7	13	27	0	7
		11	12	12	1	0	1	1	1	0
15	89	84	92	92	8	0	8	8	8	0
		9	2	0	3	5	13	1	6	0
16	89	69	15	0	23	39	100	8	46	0
		1	12	17	14	1	8	0	2	0
19	89	7	80	47	93	7	53	0	13	0
		14	1	14	0	11	0	0	2	0
21	94	100	7	100	0	73	0	0	15	0
		4	4	14	10	10	1	1	1	0
22	90	27	27	93	66	66	7	7	7	0
		1	5	1	6	1	6	0	1	0
24	89	14	71	14	86	15	86	0	14	0
		9	6	10	0	3	0	1	1	0
27	94	90	60	100	0	30	0	10	10	0
Sum		74	70	87	56	52	48	10	18	5
Per cent		53	50	62	41	37	34	66	13	4

Total responses for each situation, 140

TABLE IV

This Table Shows the Time Relationships Between the Right and Left Arm Responses of the Experimentally Right Dominant Group

Sub. No.	Difference in sec. between response of right and left arm		
	Situation 1	Situation 2	Situation 3
2	.0123	.0070	.0119
3	.0331	.0066	.0196
8	.0073	.0057	.0107
18	.0119	.0098	.0203
26	.0131	.0126	.0172
31	.0062	.0103	.0114
34	.0161	.0089	.0200
35	.0064	.0113	.0036
36	.0141	.0114	.0262
39	.0078	.0083	.0091
40	.0076	.0027	.0135
42	.0127	.0146	.0195
43	.0027	.0062	.0049
50	.0140	.0057	.0109
Mean	.0118	.0087	.0146

TABLE V

THIS TABLE SHOWS THE TIME RELATIONSHIPS BETWEEN THE RIGHT AND LEFT ARM RESPONSE OF THE EXPERIMENTALLY LEFT DOMINANT GROUP

Sub. No.	Difference in sec. between response of right and left arm		
	Situation 1	Situation 2	Situation 3
1	.0067	.0099	.0049
12	.0156	.0136	.0158
13	.0167	.0088	.0226
14	.0068	.0055	.0199
15	.0097	.0089	.0317
23	.0069	.0133	.0063
28	.0091	.0113	.0087
29	.0126	.0114	.0148
30	.0210	.0261	.1230
32	.0160	.0147	.0141
38	.0223	.0233	.0201
45	.0099	.0150	.0120
51	.0073	.0171	.0180
52	.0072	.0025	.0246
54	.0074	.0192	.0118
55	.0106	.0096	.0066
57	.0051	.0089	.0094
Mean	.0112	.0129	.0215

TABLE VI

THIS TABLE SHOWS THE TIME RELATIONSHIPS BETWEEN THE RIGHT AND LEFT ARM RESPONSE OF THE EXPERIMENTALLY AMBIDEXTROUS GROUP

Sub. No.	Difference in sec. between response of right and left arm		
	Situation 1	Situation 2	Situation 3
7	.0095	.0092	.0120
9	.0098	.0046	.0066
11	.0108	.0126	.0126
16	.0043	.0046	.0082
19	.0060	.0072	.0102
22	.0121	.0149	.0144
24	.0059	.0043	.0106
21	.0246	.0171	.0115
27	.0117	.0381	.0124
Mean	.0105	.0125	.0109

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The Relationship of Dominance to Acts of Skill

By O. H. Vogel

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BY MEANS of the technique described by Tuttle and Travis [1] the relationship of dominance [2] to performing acts of skill such as batting and throwing a baseball was studied.

Twenty members of the varsity baseball team were used as subjects. The dominance of these subjects was experimentally measured by the technique described as situation 3. A summary of the data collected from this group is shown in Table I. A comparison of the dominance as measured by the laterality index and dominance as experimentally determined with the batting and throwing habits of the group is shown in Table II. The data show that in 50 per cent of the subjects the two indices agree. In three cases there is a reversal. These subjects are right-handed as measured by the laterality index but experimentally left dominant. Of the remaining subjects, four are experimentally right dominant but ambidextrous according to the laterality index. Two subjects are experimentally left dominant but ambidextrous when classified by the laterality index.

The data show also that there are seven experimentally right dominant subjects, and all of them throw and bat right-handed. Three of this group are socially right-handed and four of them are ambidextrous according to the laterality index (see Table III).

There are eleven experimentally left dominant subjects. Six of them bat and throw right-handed. Four of these are right-handed, one left-handed, and one ambidextrous as classified by the laterality index. Two of this group bat and throw left-handed. One is left-handed and one ambidextrous according to the laterality index classification. Two of the group bat right-handed and throw left-handed. The laterality index shows both of these to be left-handed. One of the eleven bats left-handed and throws right-handed. The laterality index places him in the ambidextrous group.

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[1] W. W. Tuttle and L. E. Travis, "The Relation of Precedence of Movement in Homologous Structure to Handedness." 1935. This monograph, p. 3.

[2] Dominance as used in this discussion refers to the precedent of movement in homologous structures, that is, the forearm.

TABLE I

A Summary of the Data Collected from University Baseball Players

Sub. No.	No. right responses	Per cent right responses	No. left responses	Per cent left responses	No. simultaneous responses	Per cent simultaneous responses
8	14	94	1	6	0	0
9	7	47	5	33	3	20
10	2	13	12	80	1	7
11	12	80	2	13	1	7
12	0	0	16	100	0	0
13	0	0	15	100	0	0
14	2	18	9	82	0	0
15	12	92	1	8	0	0
16	0	0	13	100	0	0
17	0	0	14	88	2	12
19	7	47	8	53	0	0
20	0	0	13	100	0	0
21	14	100	0	0	0	0
22	14	93	1	7	0	0
23	2	13	14	87	0	0
24	1	14	8	86	0	0
58	2	20	6	86	0	0
59	2	16	12	84	0	0
60	13	100	0	0	0	0
61	20	100	0	0	0	0

There are two baseball players who are experimentally ambidextrous. They both bat and throw right-handed. The laterality index also shows them to be ambidextrous.

Here, the data suggest that the experimentally right dominant group is of a purer type, since the members of the group perform the acts of both batting and throwing with the right arm. Even though the laterality index classifies them as ambidextrous, the lowest one is only six points

under the limit for right dominance. Evidently, then, they had learned to perform a limited number of manual acts with the left hand.

The experimentally left dominant group contains four right, four left, and three ambidextrous individuals as classified by the laterality

TABLE II

A Summary of the Throwing and Batting Habits of Twenty Baseball Players Together with Their Dominant Indices

Sub. No.	Laterality Index	Bats		Throws		Physiological Dominance
		Right	Left	Right	Left	
8	100 R	x		x		94 R
9	95 A	x		x		47 A
10	97 R	x		x		13 L
11	94 A	x		x		80 R
12	7 L	x			x	0 L
13	34 L	x		x		0 L
14	30 L	x			x	18 L
15	89 A	x		x		92 R
16	89 A	x		x		0 L
17	99 R	x		x		0 L
19	89 A	x		x		47 A
20	36 L		x		x	0 L
21	94 A	x		x		100 R
22	90 A	x		x		93 R
23	30 L		x		x	13 L
24	89 A		x	x		14 L
58	97 R	x		x		20 L
59	97 R	x		x		16 L
60	97 R	x		x		100 R
61	100 R	x		x		100 R

TABLE III

Showing Grouping of Social and Physiological Dominance of Baseball Players

Handedness	Social Dominance per laterality index			Batting		Throwing		Physiological Dominance
	R	L	Amb.	R	L	R	L	
R	3	0	4	7	0	7	0	7
L	4	4	3	8	3	7	4	11
Amb.	0	0	2	2	0	2	0	2

index. Here the dominance of right-handed usage in manual acts evidently is the influencing factor. Four of the lefts learned the use of the right hand for carrying out practically all manual acts, while three of them learned the use of the right hand for a few of the manual acts. The influence of social partiality for the right hand is shown here. This is further shown by the fact that although there are eleven experimentally

left dominant players, there are only four left-handed throwers, and three left-handed batters.

The tendency of the experimentally right-handed individuals to be socially mixed is illustrated by the fact that two of the subjects bat right and throw left and one bats left and throws right. The influence of social custom is shown by the fact that four of the left dominant are socially right.

SUMMARY AND CONCLUSIONS

A study of the manual habits of baseball players shows that experimentally right dominant individuals both throw and bat right-handed. The experimentally left dominant individuals show a mixed behavior in performing the acts of batting and throwing. However, the majority of them show right-handed response. The experimentally ambidextrous individuals show right-handed performance.

An Analysis of Movement on the Basis of Latent Times and Variabilities*

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When one attempts to study the responses of an individual, the two most outstanding points which appear are the length of time elapsing between the stimulus and the response, and the variability of this time. It is also obvious from experimentation that when a movement is executed by the neuro-muscular system where the spinal cord is chiefly involved, the elapsed time between the stimulus and response is materially shorter and less variable than in cases where the cortex is brought more into the picture.

It is what one might call tradition to explain the difference between movements involving chiefly the spinal cord and those involving the cortex by saying that the former movements are reflex while the latter are voluntary. By this statement it is assumed one means that voluntary movements are under the control of what psychologists call volition, while reflex movements are not under the conscious control of the organism.

From the standpoint of neuro-physiology, the reflex-will concept is scarcely an explanation of movement, but is rather a philosophical way of disposing of the question. The investigation presented here is an attempt to obtain data which will serve to establish a more scientific classification of movement.

In an attempt to gain information as to the neuro-physiological differences between different movements, a group of responses was selected which seems to be representative of all types. As a representative of what is generally designated as reflex response, the Achilles jerk was selected. As a typical voluntary reaction, the individual responded by extending the foot at the appearance of a light stimulus. In order to establish a response paralleling a more complicated type of behavior, the individual responded to a choice light stimulus by extending the foot. Throughout, the experiment consisted of holding constant the effector mechanism, including the final common path, while varying the stimulus pattern.

* From the Department of Physiology, College of Medicine, State University of Iowa. This is an excerpt of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

In addition, the reflex arc involved in the Achilles reflex was analyzed into its constituent parts, in order to establish a natural check on the experimental procedures. Also, the results of the muscle-thickening technique, which was used throughout the main part of the experiment, were compared with results of the method where gross movement of the member to which the muscle is attached was used as the index of response.

It is generally conceded that when a movement is executed, the nerve impulse involved encounters resistance to its passage in five mechanisms, viz., in the receptor, in its passage over the nerve trunk, at the synapse, at the myoneural junction, and in the effector. Utilizing this concept of resistances to the passage of the nerve impulse involved in the execution of movement, it seems possible to establish a classification of movement on the basis of the amount of the nervous system functioning in the act.

If our concept of resistance is true, then it is evident that, as a stimulus pattern becomes more complicated, more and more of the nervous system becomes involved; in other words, more and more neurons are brought into play. If this is the case, then the more neurons involved in a movement, the greater will be the resistance to the passage of the nerve impulse, and the longer the latent time of the response.

Furthermore, as the neural pattern becomes more complex, one would expect that more of the receptive system would have an avenue of approach into the final common path, thus causing a greater variability in the response. If this is correct, then the variability of the latent time of the response would also be an index to the complexity of the neural pattern.

If, by experimentation, one can substantiate the resistance concept, then it is logical to account for the differences in latent times and variabilities by the fact that the neural patterns are different. It is possible to gradate movement, beginning with the simplest one, such as the Achilles reflex, and to go on through the nervous system to the point where the neural pattern possibilities are exhausted.

In order to throw some light on this question, the investigation herein reported was undertaken. The approach to the problem consists in holding as many of the resistance mechanisms constant as possible, and varying the number of neurons involved by changing the stimulus pattern.

The response mechanism used was the thickening of the gastrocnemius muscle.[1] This eliminates variability in resistance as far as the myoneural junction and the muscle is concerned. The receptors involved were those in the retina and in the Achilles tendon. Reliable informa-

[1] The fact was not overlooked that when the foot is extended the soleus, as well as the gastrocnemius, is involved in the movement.

tion concerning the latencies of these receptors is not available; therefore they were necessarily variables in the experiment. The differences in lengths of the nerve trunk involved were so small that they were not regarded as influencing factors. The chief resistance variable in the experiment was then the neurons and synapses involved.

REVIEW OF LITERATURE

Before proceeding to the experiment, a review of literature dealing with resistances in the various parts of the nervous system, as shown by latent times, is presented.

Following is a summary of the data collected by other investigators concerning the latencies involved in the Achilles jerk.†

LATENCY OF THE ACHILLES REFLEX

A. Action Current Method

	Average time	Range
Hoffman (1)		31.0 to 36.0 sigma
Dodge (2)	35 sigma	
Tuttle, Travis, and Hunter (3)	34.7	25.1 to 38.1
Travis and Young (4)	32.2	28.8 to 36.5
Nystrom (5)	33.7	29.5 to 37.0

B. Muscle-Thickening Method

	Average time	Range
Dodge (2)	50.0 sigma	
Rounds (6)	54.0	32.0 to 96.0 sigma
Nystrom (5)	45.5	29.5 to 53.5

LATENCY OF THE GASTROCNEMIUS MUSCLE

Gross Movement Method

	Average time	Range
Royal (7)	24.0 sigma	21.0 to 27.0 sigma
Affre (8)	26.0	20.0 to 31.0
Wendler (9)	25.0	17.0 to 29.0
Denkmann (10)	24.0	

There is but little available information relative to receptor latency which has any direct bearing on this study. The same is true of the resistance of the myoneural junction. Herren and Lindsley (11) found the receptor latency for the Achilles reflex in rats to be one sigma and the myoneural junction latency to be about three sigma.

At the present time, the consensus of opinion is that the velocity of nerve impulse propagation is not uniform for all the fibers in any mixed nerve. The present status of the investigations of the speed of the nerve impulse makes it impossible to give figures for the pathways involved in this experiment.

Concerning reaction time for the movements employed in this study the literature yields no figures.

In order to investigate the difference between movements, from the standpoint of resistance and variability, the latent times of four responses

† Numbers refer to bibliography.

were studied and compared. The movements were as follows: (1) the thickening of the gastrocnemius muscle on electrical stimulation of the motor point, (2) the Achilles jerk, (3) the thickening of the gastrocnemius muscle at a given light stimulus (simple reaction time), and (4) muscle-thickening response to a choice light stimulus (choice reaction time).

APPARATUS EMPLOYED

The four movements investigated necessitated the development of three stimulating units and a recording device for measuring muscle thickening time. The separation of the Achilles reflex into components

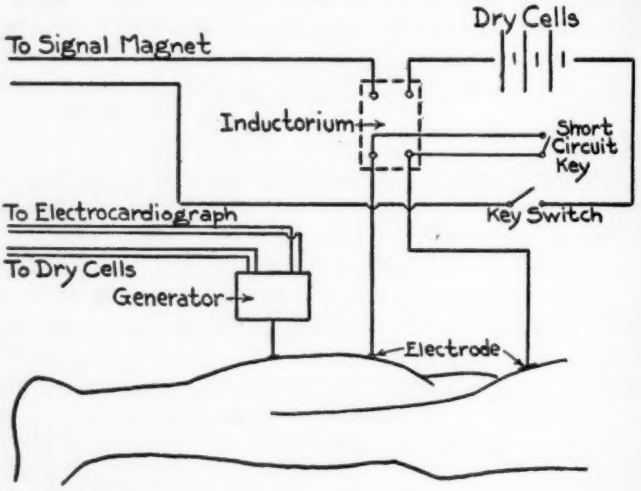


FIG. 1.—The arrangement of the apparatus for measuring muscle-thickening latency.

of muscle thickening latency and conduction latency required apparatus for recording action currents. A comparison of the muscle thickening with gross reflex latency necessitated provision for recording the movements of the foot. Each piece of apparatus is discussed separately.

Muscle-Thickening Latency.—The arrangement of the apparatus for measuring muscle thickening latency is shown in Fig. 1. In order to stimulate the muscle directly, two electrodes covered with canton flannel and moistened with a saturated saline solution were employed. One of them, consisting of a copper ball ¼″ in diameter, was placed over the motor point of the muscle. The other one was a brass plate 1″ x 1¾″, placed on the thigh away from motor points. The electrodes were connected to the secondary of an inductorium. The make stimuli were avoided by means of the short circuit key. In order to record the time of the application of the stimulus a signal magnet was placed in series

with the stimulus key and three dry cells. The signal magnet was placed in front of a recording camera which will be described later.

In order to detect the beginning of the muscle thickening, a special generator was constructed, as shown in Fig. 2. The generator consisted of a steel core suspended in a soft iron cylinder from a transverse iron base. About 200 turns of No. 16 insulated copper wire were wound on the bottom of the core. These turns of wire terminated in two connections on the base. This constituted the field coil. In order to magnetize the steel core, a 110-volt D.C. current was passed through the coil at frequent intervals. When the coil was in use, two dry cells were connected through the field in order to increase its magnetic power.

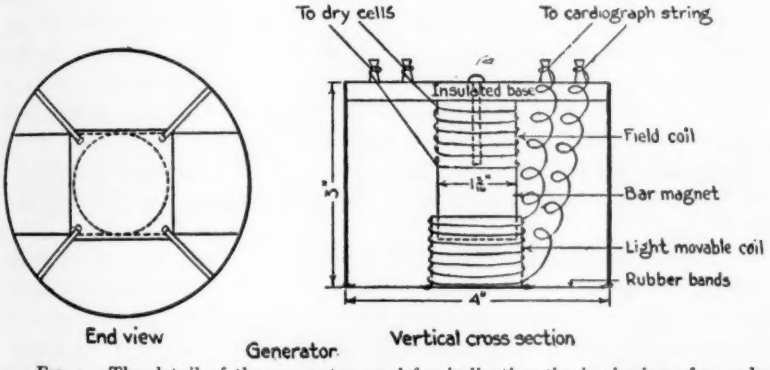


FIG. 2.—The detail of the generator used for indicating the beginning of muscle thickening.

A light moveable coil consisting of 150 turns of No. 34 insulated copper wire wound on a cardboard spool was suspended from the open end of the cylinder over the field core, by means of 4 rubber bands (end view, Fig. 2). The ends of the wire wound on the spool terminated in 2 connections placed on the base. The sensitivity of the arrangement was proved by the fact that the slightest movement of this coil generated a sufficient amount of electricity for detection by a string galvanometer.

The generator was applied to the muscle as shown by Fig. 3. A small piece of thin copper was attached to the light aluminum rod. The copper plate was attached to the rod so that it was free to adapt itself to the muscle. The generator was placed in such proximity to the muscle that when the rod was placed between the muscle and the generator, slight tension was placed on the moveable coil.

The string galvanometer employed was a standard Cambridge type used in connection with the electrocardiograph. In order to adapt it to our problem some modifications were necessary.

In order to produce ordinate time lines of 1/100 sec. it was necessary

to replace the 5-spoked wheel on the synchronous motor timer with one containing 20 spokes. The twentieth spoke was omitted so as to facilitate reading long records.

The camera was altered to permit the use of 35 mm. Eastman recording paper instead of the standard electrocardiograph width. This was done by placing a steel disc guide on the shaft in the magazine. The guide served to cause the paper to be drawn straight past the lens in the aperture of the camera.

It was also found necessary to increase the speed of the camera from 13 to 150 R.P.M. This was done by a system of belts and pulleys.

In order to record muscle-thickening time, the signal magnet in series with the stimulus key was placed in front of the aperture of the camera so that the shadow of the stylus fell near one edge of the paper. The galvanometer string was focused on the paper in close proximity to the stylus. When the camera was running at full speed, the lens was opened at the same time the clutch was engaged. The camera was kept in operation until the muscle had responded to the stimulus. The latent time of the muscle thickening was determined by counting the ordinates on the paper, each representing 1/100 sec. A sample record is shown in Fig. 5.

Achilles Reflex Latency.—The Achilles reflex was elicited by striking the Achilles tendon a sharp blow by means of a hammer adapted for this purpose. The details of the hammer are shown in Fig. 6. It is arranged with a moveable head set in a rubber plug so that the instant the tendon is struck a circuit containing a signal magnet and a dry cell is closed. The signal magnet stylus is placed in front of the camera as previously described.

The beginning of the Achilles reflex response is measured by means of the muscle-thickening technique already described (Fig. 3). The

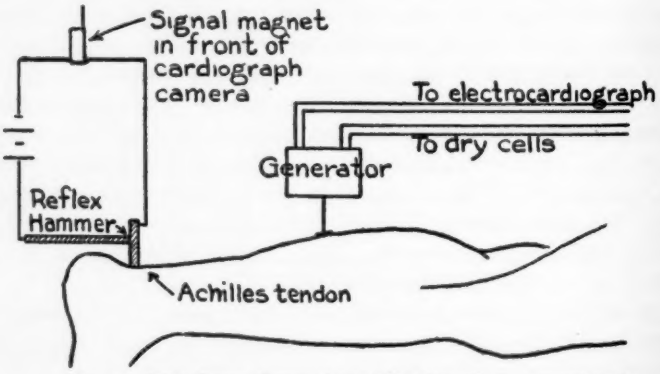


FIG. 3.—This figure shows the application of the generator to the muscle.

latent time for the reflex is calculated in the same manner as the latency of muscle thickening. Sample records are shown in Fig. 7.

Simple Reaction Time.—The simple reaction consisted of responding to a single light stimulus by contracting the gastrocnemius muscle. The arrangement of the stimulus unit is shown in Fig. 9. A switch *4a*, is connected in series with a six-volt storage battery, two dry cells, the back magnet on a Dunlap chronoscope, and on a six-volt pilot bulb. Simul-

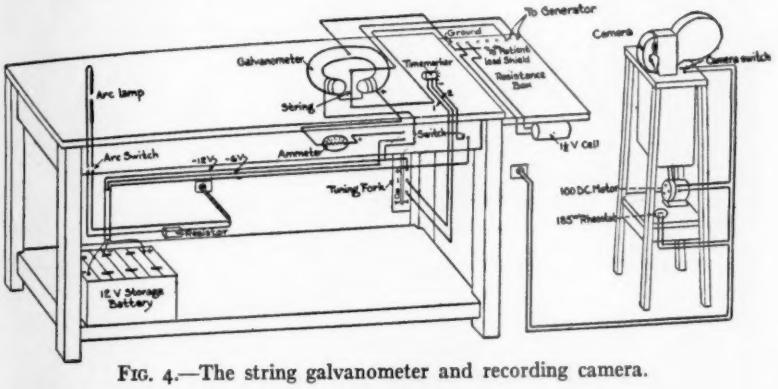


FIG. 4.—The string galvanometer and recording camera.

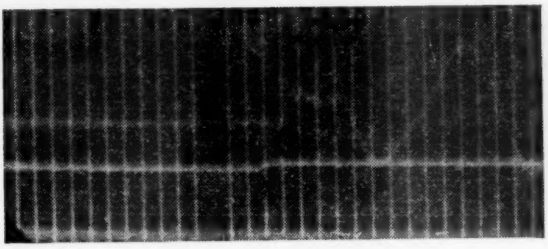


FIG. 5.—A record of muscle-thickening latency. *A*, the stimulus and *C*, the beginning of the response.

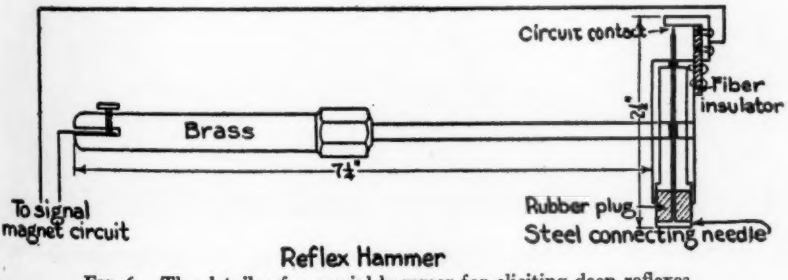


FIG. 6.—The details of a special hammer for eliciting deep reflexes.

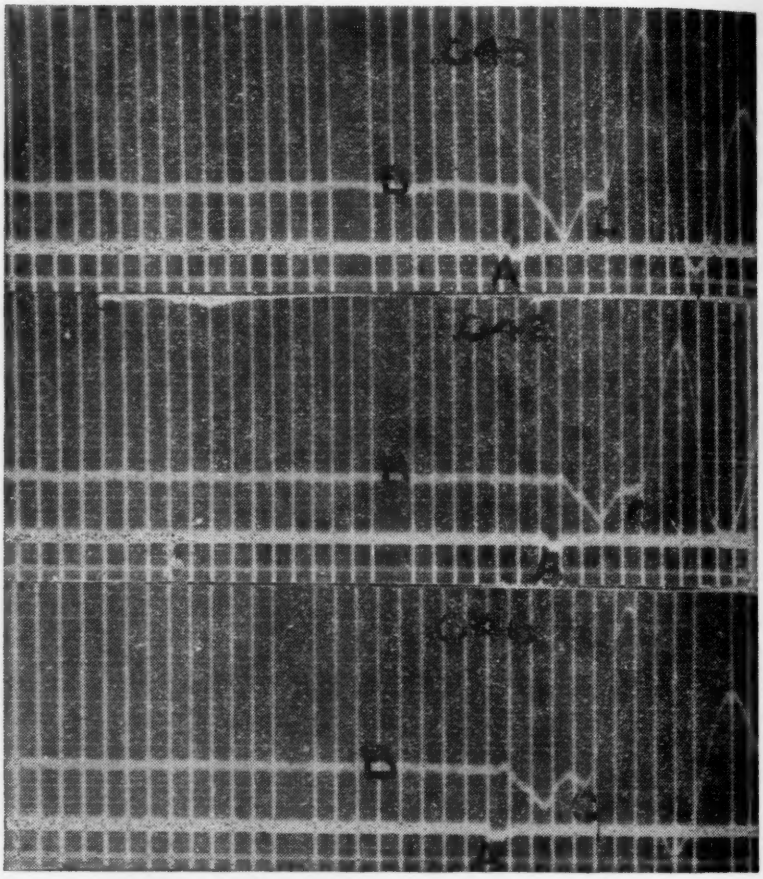


FIG. 7.—Records of the latent time of the Achilles Reflex. *A*, the stimulus and *C*, the beginning of muscle thickening.

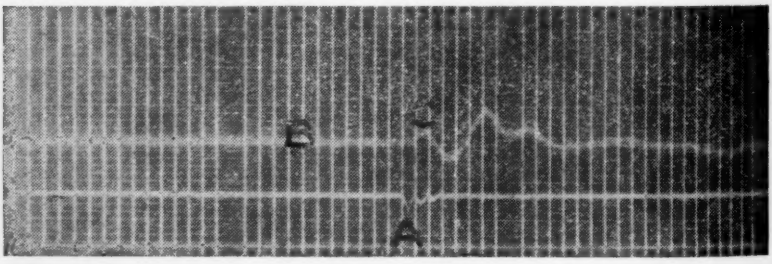
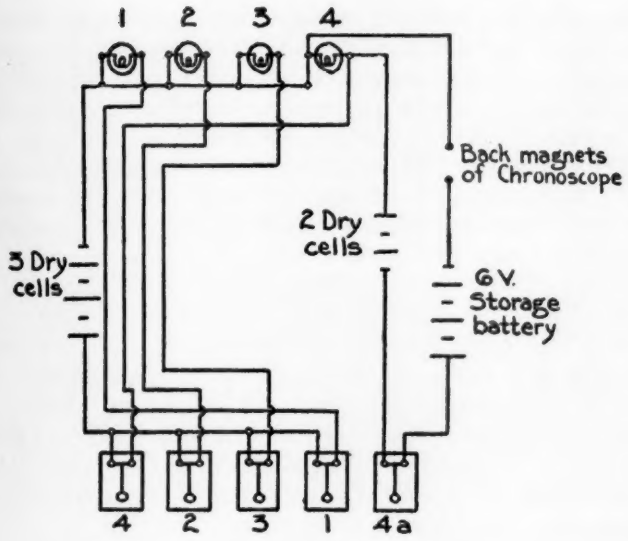
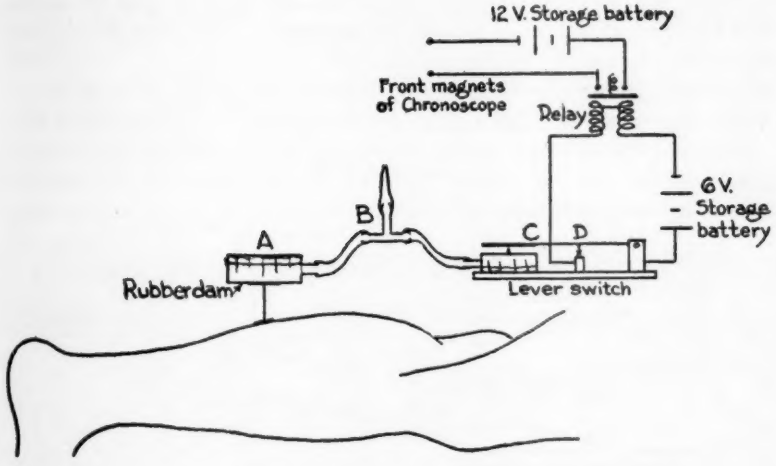


FIG. 8.—This record of reflex latency cannot be read due to a synchronization of jar and response.



Dunlap Chronoscope Stimulus Unit

FIG. 9.—The arrangement of the apparatus for determining stimuli in the simple and choice reaction experiment.



Dunlap Chronoscope Response Unit

FIG. 10.—The apparatus used for stopping the chronoscope by the thickening of muscle.

taneously with the showing of the light, the dial hand on the chronoscope is started. The subject responds to the light as quickly as possible by contracting the gastrocnemius muscle which stops the chronoscope.

The arrangement of the apparatus for stopping the chronoscope by the thickening of the gastrocnemius muscle is shown in Fig. 10. A tambour, *A*, was connected by rubber hose to a pneumatic reaction key. The air column contained a T-tube (*B*) with a slow-leak arrangement so that the column of air was always adjusted to the surrounding air pressure. This arrangement unified the position of the break lever after each response so that the contacts could be finely adjusted. The pneumatic switch was connected through a six-volt storage battery to a relay. Since, when the muscle was in a resting state, the pneumatic switch was closed, the relay circuit was also closed. As soon as the muscle began to thicken, the relay circuit was broken at *D*. As soon as the relay circuit was broken it closed a twelve-volt storage battery circuit to the front chronoscope magnet and the dial hand was instantly stopped. It will be remembered that the chronoscope was started by the stimulus key. The simple reaction time is read from the chronoscope dial.

Choice Reaction Time.—In this part of the experiment the subject was instructed to respond to light 4, Fig. 9, when it was preceded by lights 3 and 1 in the order named. The stimulus pattern was light 3, 1, and 4. In order to avoid starting the chronoscope when false sequences were given, light 4 was in two circuits, one which started the chronoscope and one which did not. The scheme for starting the chronoscope when the stimulus was given and for stopping it by the thickening of the muscle was the same as described for the simple reaction time. The arrangement for giving the stimuli is shown in Fig. 9.

Action Currents.—The latency of the Achilles reflex as expressed by action currents was obtained as follows: Action current electrodes were placed, one on either side of the motor point of the gastrocnemius muscle, about one-half inch apart (see Fig. 11). The electrodes were attached to the string of the electrocardiograph. When the apparatus was in place,

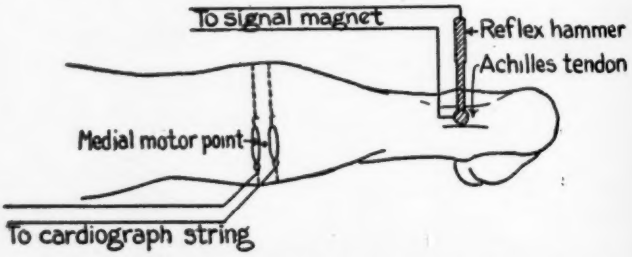


FIG. 11.—The arrangement of the apparatus for measuring the latency of the Achilles reflex using the action current as the index of the beginning of response.

the camera was started and the tendon struck a sharp blow with the reflex hammer previously described. The arrangement of the apparatus is shown in Fig. 11 and a sample action current record in Fig. 12.

Gross Movement Muscle Latency.—In order to record gross movement muscle latency the rod used for connecting the muscle to the generator previously described was attached to the subject's foot. The generator was fastened to a stand and placed in such proximity to the foot that the slightest movement activated the generator, which was in

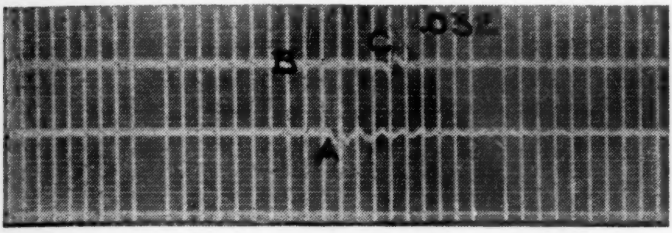


FIG. 12.—The action current taken from the gastrocnemius muscle when the Achilles tendon was stimulated.

series with the string of the electrocardiograph. The arrangement of the apparatus is shown in Fig. 13. The gastrocnemius muscle was activated through its motor point as described in the discussion of muscle-thickening latency and the records were made in the same way. Sample records of gross movement latency are shown in Fig. 14.

Gross Reflex Time.—In order to record gross reflex time in the Achilles reflex the generator was left in the same position as it was when gross muscle latency was measured (see Fig. 13). The reflex was elicited

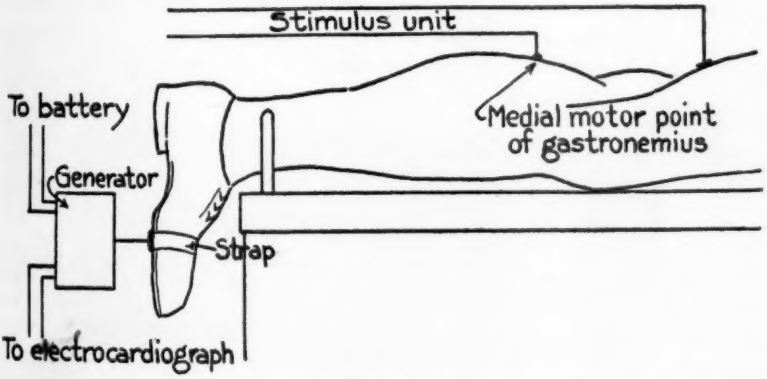


FIG. 13.—The arrangement of the apparatus for recording gross movement latency of the gastrocnemius muscle.

by striking the Achilles tendon a sharp blow with the reflex hammer. The records were made the same as in muscle-thickening reflex time. Sample records are shown in Fig. 15.

THE DATA

Data were collected from a group of thirty subjects, and include seven different latencies. Each experiment is presented separately.

1. *Muscle-Thickening Latency.*—Data were collected from 30 different male subjects. When the subject came to the laboratory he assumed a comfortable prone position on a padded table. When the apparatus was adjusted to him, records of his muscle-thickening latency were recorded. In all of the experiments, the right leg was used. It was

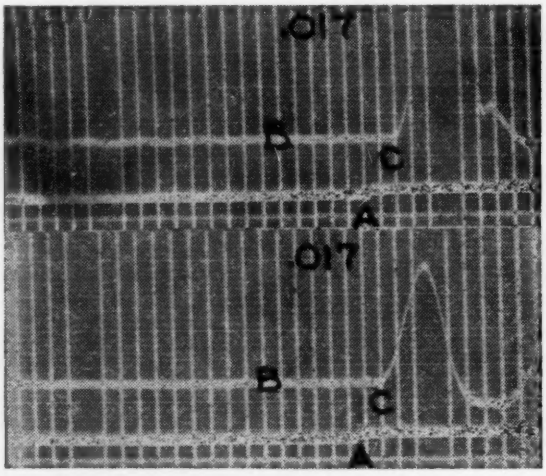


FIG. 14.—Records of gross movement latency. *A* is the stimulus and *C*, the response.

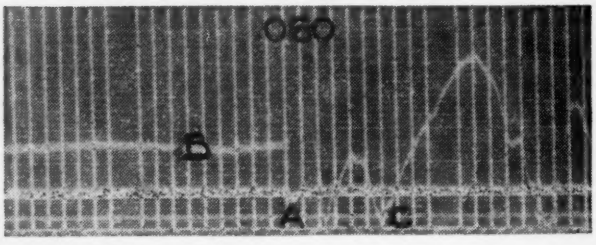


FIG. 15.—A record of gross movement latency. *A* is the stimulus and *C*, the response.

intended to have 15 records from each subject, since other investigators in this laboratory have proved that number to be sufficient to establish a reliable mean. Due to photographic difficulties, only 5 records were secured in two cases, but for the most part 15 or more records were obtained. The mean latent time of the muscle thickening after electrical stimulation of the motor point was found to be 15.1 sigma with a standard deviation of 2.8 sigma.

2. *Gross Movement Latency.*—The latent time of the gastrocnemius muscle thickening was measured in 24 cases, where the first movement of the foot was used as the index of response. The subject remained in the same position as in the muscle-thickening experiment. The apparatus was adjusted to the toe of his shoe as previously described. Again, the aim was to secure 15 readings but, as before, less than this number was secured in some cases. The mean latent time for the movement of the foot after the motor point of the gastrocnemius muscle was stimulated was 17.9 sigma with a standard deviation of 2.9 sigma.

3. *The Latent Time of the Achilles Reflex as Measured by Action Currents.*—With the subject remaining in a prone position, the stimulating electrodes were replaced by action current electrodes. Action currents set up in the gastrocnemius muscle by striking the Achilles tendon a sharp blow were recorded for 30 subjects. The mean reflex time was found to be 32.8 sigma, with a standard deviation of 2.7 sigma.

4. *The Latent Time of the Achilles Reflex Measured by Muscle Thickening.*—Because of the difficulty encountered with the muscle-thickening measurement of reflex latencies, only 19 of the 30 subjects gave records which could be read. The muscle jar elicited by a blow on the Achilles tendon caused a vibration which, when photographed, fitted perfectly into the record of the reflex movement of the muscle in a number of cases. Fig. 8 illustrates this point. The mean reflex latency by this method was found to be 47.3 sigma, with a standard deviation of 5.9 sigma.

5. *The Latent Time of the Achilles Reflex as Shown by the Foot Movement.*—While the subject was lying in a prone position, the generator was attached to the foot and the Achilles tendon struck a sharp blow. Records were made of the gross movement latency of the Achilles reflex in 24 cases. The mean latent time of the reflex was found to be 57.7 sigma with a standard deviation of 6.9.

6. *Simple Reaction Time.*—In this part of the experiment the subject was placed prone on a table and the apparatus was adjusted to him as previously described. The light stimulus was placed on the floor in front of him. The chronoscope was placed in an adjoining room with the door closed during the experiment. As an added precaution against distracting noises a water tap in the room was allowed to run.

When all was in readiness the subject was directed to respond by

extending the foot as quickly as possible after seeing the light stimulus. The subject was also aware of the fact that some time before each flash of light, the operator would speak a number. This served as a warning signal as well as a method for counting the number of responses. The interval between the warning signal and the stimulus was varied, preventing the formation of a response habit. The general aim was to take 150 to 200 records of this response, although in a number of instances the total fell short of this figure. The responses were recorded in groups of 25, a rest period being allowed between sets. In each case the subjects were allowed 25 practice trials. It should also be added that in the treatment of all data involving reaction times, the 5 longest and the 5 shortest readings were eliminated, as they were probably influenced by an experimental set or by distractions of one kind or another. These accidents would have an undue effect on the means, as an exaggerated result would appear in the standard deviation due to the squaring of these "sport" readings. The readings were recorded on a frequency distribution chart. Twenty-nine subjects were available. The mean reaction time was found to be 332.4 sigma with a standard deviation of 44.5.

7. *Choice Reaction Time.*—The instructions were the same for the choice reaction response as for the simple reaction series except that the subjects were directed to respond to a light stimulus in a series pattern, viz., light 4 when it was preceded by lights 3 and 1 in the order named (Fig. 9). False series were introduced at random so that the subject could respond correctly only when he attended to the stimulus pattern. Each subject was given 25 or 30 practice trials in order to learn the stimulus pattern. For the most part, 200 readings were made for each subject. They were recorded in groups of 25 with a short rest period between series. For both simple and choice reactions, the subject was allowed to get off the table and walk about at the end of 100 trials.

Data were collected from 28 subjects. The data show that the mean choice reaction time is 410.7 sigma with a standard deviation of 54.6 sigma.

There are several points of interest brought out by the experiment, which are set forth in the discussion.

DISCUSSION

In making some of the comparisons it is necessary to omit some of the data since comparable figures could not be secured on all subjects.

Muscle-Thickening Latency as Compared with Gross Movement Latency.—Twenty-four subjects yielded data for both muscle-thickening and gross movement latency. When the motor point of the gastrocnemius muscle was stimulated, the mean latent time for muscle thickening was 14.9 sigma with a standard deviation of 2.4 sigma. The mean latent time for the movement of the foot when the same motor point was stimulated

was 18.1 sigma with a standard deviation of 2.7 sigma. Evidently 3.2 sigma were lost in getting the anatomical mechanisms into action.

A Comparison of Achilles Tendon Reflex Time by Muscle Thickening with Gross Movement Reflex Time.—Thirteen subjects gave both muscle-thickening and gross movement reflex time. The muscle-thickening reflex time was found to be 46.5 sigma with a standard deviation of 3.6 sigma. The mean gross-movement reflex time was 59.8 sigma with a standard deviation of 5.7 sigma. The data thus show the muscle-thickening reflex time to be shorter and less variable than the gross reflex time.

Reflex Arc Additive Properties.—Data obtained on the additive properties of the reflex arc suggest some physiological points of interest, and also serve as a check on the accuracy and reliability of methods employed in the experiment. Nineteen subjects yielded the data upon which this part of the investigation is based.

In this part of the experiment the reflex arc was broken into two resisting parts, the receptor, synapses, nerve trunks and myoneural junction representing one, and the effector the other. It is logical to assume that by adding the latent time of the former resisting mechanism to the latent time of the muscle, one should have a sum representing the reflex time of the mechanism. In order to test this assumption, a comparison has been made between the Achilles reflex latency (muscle-thickening technique) and the sum of muscle-thickening latency and action-current latency. Comparisons were made for 19 subjects. The data show that when the mean muscle thickening latency (14.9 sigma) is added to the mean action-current latency (32.89 sigma), a figure is obtained (47.84 sigma) which is nearly the same as the mean reflex muscle-thickening time (47.32 sigma). This is not true when gross movement reflex time is substituted for muscle-thickening reflex time. In 8 of the 19 cases the data are exactly the same, and in no case is the difference greater than 4 sigma. Due to chance it might be possible to get 19 cases to check this closely, but it seems logical that some other reason must exist.

The electrical stimulus in the muscle-latency experiment and the nerve impulse in the Achilles reflex arc enter the muscle at or near the same place. It should require about the same time for the impulse in both cases to become disseminated through the muscle to produce a response.

The data seem to show that the reflex arc can be broken into at least two parts, represented by the muscle and by the receptor plus the conducting system of neurons. Since Travis and Young (4) were able to show a correlation of .790 $\pm$ .040 between height and conduction time in the Achilles reflex, and since muscle latency is evidently a function of structure, then reflex latency is evidently dependent upon at

least the factors of height, resistance of the synapse, and muscle structure.

An Analysis of Movement on the Basis of Latent Time.—As previously stated, the main object of this experiment was to furnish a neuro-physiological basis for the classification of movement. For this purpose a distribution table was made of the mean latencies and the standard deviations for 29 subjects. Statistical analysis of these figures yielded the following results:

	Mean sigma	*Range of distribution*	*Average of standard deviations*	*Standard deviation of distribution*
Latent time, muscle-thickening technique	15.2	13	1.5	2.8
Reflex time	47.9	18	2.1	5.9
Simple reaction time	332.4	221	34.2	44.5
Choice reaction time	410.7	234	61.6	54.6

On examination of the neural structures involved in the movements above one finds the following: First, the muscle-thickening response on stimulation of a motor point does not involve the nervous system; second, the Achilles reflex involves two or three neurons; third, the simple reaction response brings into play a minimum of eight neurons; and fourth, the choice reaction act adds additional neurons to the simple reaction pattern.§

When the data above are considered in the light of the neural structures involved in the different movements, it becomes apparent that as we go from a reflex pattern of two or three neurons to one of eight or more neurons, there is a corresponding increase in latent time and in variability. The sharp increase in latency is easily explained on the basis of synaptic resistance, while the increase in variability is evidently due to the fact that in a movement pattern which involves more of the cortex, there are greater receptive possibilities for inhibitions (distractions).

These results support a classification of movements on the basis of neural pattern, and justify a comparison of movements on the basis of the time lost in their execution, and their variability.

A comparison of the data for the simple reaction and the choice reaction shows that the difference in variability is out of proportion to the difference in latent time. Since only one or two additional neurons are brought into the pattern one would expect a small increase in latency but not so large an increase in variability. After the response stimulus is given, the neural patterns are evidently the same, but before the response, the situation is quite different. In the simple pattern, one responds only to a main stimulus, while in the choice pattern experi-

§ This concept of the neural pattern involved in the movements described was confirmed by Dr. A. R. Buchanan, Department of Anatomy, College of Medicine, State University of Iowa.

mental inhibitions are set up. It is evident from the data that these inhibitions influence variability, and the added neurons increase the resistance to the passage of the impulse.

The Reliability of Reading the Records.—A test of the reliability of reading records was made by taking one hundred random samples of records and having them read independently by two persons. The means of the independent readings checked to within one-tenth sigma and the greatest individual variation was two sigma. Assuming a difference of two sigma in the same direction in every reading, the final result would be a mean two sigma greater or smaller and would not materially affect the reliability of the results. In fact, because of the use of means, these errors in reading would tend to cancel each other, leaving a mean result which is substantially correct.

Number of Records Required for a Reliable Mean.—In order to determine the number of muscle-thickening records required to produce a reliable mean, odd scores were correlated against even scores. When 10 readings were included in the mean, the correlation was .96. The addition of 25 more scores changed the correlation to .97. It was concluded that 10 readings were sufficient.

Nystrom (5), by testing the stability of the standard deviation of various numbers of readings, concluded that five or six were sufficient to give a stable mean for both the action current and reflex muscle-thickening records taken by striking the Achilles tendon.

A correlation of odd against even readings showed that 150 simple reactions and 200 choice reactions were ample to give reliable means.

SUMMARY

The data presented in this investigation are summarized as follows:

1. The latent period of the intact human gastrocnemius muscle after electrical stimulation of its motor point was found to be 15.1 sigma, with a standard deviation of 2.8 sigma, when measured by the muscle-thickening technique. It was 17.9 sigma, with a standard deviation of 2.9 sigma, when measured by the gross movement technique.

2. The action current latency of the Achilles tendon reflex was 32.8 sigma, with a standard deviation of 2.7 sigma.

3. The Achilles reflex latency, measured by the muscle-thickening technique, was 47.7 sigma, with a standard deviation of 2.1 sigma. It was 57.8 sigma with a standard deviation of 5.9 sigma, when measured by the gross movement method.

4. Simple reaction to a single light stimulus, when responding by thickening the gastrocnemius muscle, was 332.4 sigma, with a standard deviation of 44.5 sigma.

5. Choice reaction time, where the thickening of the gastrocnemius was used as the index of response, was 410.7 sigma, with a standard deviation of 54.6 sigma.

6. Reflex latency based on action currents plus muscle-thickening latency equals reflex latency based on muscle thickening, which is evidence that the techniques employed were accurate and reliable.

CONCLUSIONS

The data presented in this investigation show that movements can be compared neurologically by studying their latent time and the variability of this time, since the number of neurons involved varies directly with the latent time and variability of the movement. However, no evidence was presented which makes a quantitative classification of movements possible, since there is no definite clue as to the exact numbers of neurons involved in any movement.

Neurologically, it is evident that movements differ only as the number of neurons involved differ. On the basis of the data presented, movements depend on the neural pattern, which in turn depends on the stimulus pattern. From this standpoint, all movements are, in general, alike, the only difference being in the amount of nervous system involved.

On the basis of the data presented it is suggested that instead of calling some movements reflex and some voluntary they be classified according to the complexity of the pattern of neurons involved.

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The Effect of Exercises of Graded Intensity on the Leukocyte Count

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IT HAS been pointed out by a number of investigators that physical exercise alters the number of both the red and the white blood corpuscles in the blood stream. At the present time, the increase in the cell count is believed to be due to the mobilization of additional corpuscles which lie inactive in the spleen and stagnant capillaries before the beginning of exercise. This idea is strengthened by the fact that the increase in cells is transitory and passes off shortly after the cessation of exercise.

The studies reported up to the present time have dealt with leukocytosis following many types of exercise, but no one has studied the response of the white blood cells to exercises of graded intensity, beginning with rather light exercise and ending with rather strenuous exercise. As a result, the only conclusion that can be drawn is that exercise causes leukocytosis, and no light is shed on the relationship between the severity of exercise and the extent of the increase in the number of white cells in the blood stream.

In the investigation herein reported an attempt is made to discover the relation between the severity of physical exercise and the amount of leukocytosis present after the exercise.

REVIEW OF LITERATURE

There are numerous researches reported in the literature dealing with the effect of physical exercise on the number of white cells appearing in the blood.

Burrows,[1]* in trying to account for leukocytosis after convulsions, studied the effect of exercises on one individual. Three hours after a heavy meal, when the leukocyte count was 13,000, the subject ran violently for 3 minutes, reaching the point of first exhaustion. The leukocyte count after the exercise was 17,000. After 20 minutes of reclining rest the count was 11,400. Forty minutes later the subject reached the point of extreme fatigue by a long run. After this exercise, the leukocyte count

* Numbers refer to bibliography at end of article.

was 8,800. After 30 minutes rest the count was 8,900. In each case, the differential count was made, and on the basis of this it was concluded that the leukocytosis after the first exercise was not of the inflammatory type.

Larrabee[2] studied the blood of 4 of the contestants in the Boston Athletic Association's marathon race in 1901. The distance over which the contestants ran was 40 kilometers. The blood of the contestants before the race showed no abnormalities. In every case after the race a leukocytosis was found. Before the race the leukocyte count for the contestants was 4,800, 5,800, 3,700, and 8,200 respectively. Following the race the count was 14,400, 16,200, 20,800, and 22,200 respectively. On the basis of the differential count it is concluded that violent prolonged exhaustive work produces a leukocytosis characterized principally by an increase in the polymorphonuclear cells, but also including a considerable increase in other forms. It is suggested that more than one cause acts to produce leukocytosis after violent physical exercise, probably a temporary, mechanical cause, and a toxic cause which is more slow to develop but which lasts as long as the exercise continues.

Willebrand[3] studied the blood of twelve subjects after ten minutes of gymnastic exercise. After the exercise there was a mean increase of 47 per cent in the leukocyte count.

Hawk[4] investigated the leukocyte count after exercises which included sprinting, running, broad-jumping, walking, swimming, and bicycle rides of various durations. The results of the experiment showed that there was leukocytosis in every case, varying from a mean of 44.1 per cent to 73.4 per cent. The most severe leukocytosis occurred after fifteen minutes of swimming. Hawk suggests that the explanation for leukocytosis after exercise lies in the changed distribution of the cells. The greatly increased rapidity of circulation throws out great numbers of leukocytes from the large blood vessels and lymphatics of the interior into the smaller arterioles and vessels where the circulation is slower. This would cause the leukocytes to lag behind the general blood stream and thus produce a leukocytosis of large dimensions.

Garrey[5] suggests that if one is to investigate the leukocyte count, the studies should be made referable to a norm established by a definite basal state. In order to establish a norm, basal conditions with absolute rest in the recumbent position are recommended. It was found that under such conditions the leukocyte count falls, reaching its lowest level in about an hour. Garrey reports that under ordinary conditions this low level can be induced at any time of day and is independent of previous meals. It is also pointed out that if the basal level is to be reached and maintained, the individual must remain quiet, mentally relaxed, and free from all bodily discomfort. The investigation included the leukocyte count under basal condition, during ordinary activity (the activity level), and after

various types of muscular exercise. In 95 per cent of the cases studied the basal count varied between 5,000 and 6,000. During ordinary activity the count was between 8,000 and 10,000, and in 10 per cent of the cases even higher. Mild exercises, such as a few knee-bends, increased the count to 12,000 or 13,000 within a period of 2 minutes. It was determined that the rise in the leukocyte count due to exercise increases, within limits, with the severity of the exercise. An athlete whose basal count was 5,000 had 8,000 after alternately raising and lowering his legs while in a recumbent position. The same individual experienced a greater increase after 5 minutes of raising and lowering the arms. This was apparently due to the difference in training of the muscles involved. A 100-yard dash raised the count from an activity level of 8,000 to 22,000 within 15 secs. A 440-yard dash raised the count to 26,000. A competitive quarter mile raised the count to 35,000. Garrey concludes from his study that physiologic leukocytosis is due to a readjustment of the vascular system.

A number of other researches dealing with leukocytosis after physical exercise have been reported. However, the results prove that, in general, physical exercise causes leukocytosis by bringing about a circulatory readjustment.

THE PROBLEM

The purpose of this investigation is to determine the relationship between the severity of exercise and the number of leukocytes in the circulating blood.

THE TECHNIQUE

Counting the Leukocytes.—The usual clinical method was employed in counting the leukocytes. An American standard hemocytometer with a Levy counting chamber was used.

Cognizance was taken of the work of Garrey relative to the establishment of a reference point by establishing both a basal count and an activity level. The basal count was taken after each subject had experienced bed rest for at least one hour. The activity level represents the number of cells in the circulating blood immediately after the subject came to the laboratory following such duties as attending classes or walking around the laboratory.

The blood was secured from the tip of the index fingers, no two samples being drawn from the same finger. The finger was sterilized and then punctured. Care was taken not to squeeze the blood from the wound, but to secure the blood from the drop that appeared after the puncture.

The Exercises of Graded Intensities.—Stool stepping was selected as the exercise to be used, since experience with this exercise had made the experimenter proficient in its use. The stool employed was thirteen inches high and of such dimensions that it could be easily mounted by those who

had had no experience in performing this type of exercise. The stool-stepping technique has been described in detail elsewhere by Tuttle.[6]

The exercises selected were as follows:

1. Twenty steps on the stool at the rate of 20 steps per minute.
2. Sixty steps on the stool at the rate of 20 steps per minute.
3. One hundred steps on the stool at the rate of 20 steps per minute.
4. Twenty steps performed at a maximum speed.
5. Sixty steps performed at a maximum speed.
6. One hundred steps performed at a maximum speed.

The above exercises were selected with the hope that each preceding one would be less strenuous than the one which followed it. On the basis of heart rate, the selection was well suited for the purpose (Table I).

Within ten seconds after the cessation of each exercise the blood sample was taken. Immediately after the exercise was finished the heart rate was counted. The subject was allowed to rest for at least ten minutes.

THE DATA

Data collected from 20 normal men are shown in Table I. The data show that the mean basal leukocyte count of the group was 6,810.† The mean activity level for the group was 7,676. These means fall within the range established by Garrey.[4] The mean leukocyte counts after the six exercises were about 9,300, 10,100, 9,500, 9,800, 10,600 and 12,100 respectively. The mean basal heart rate for the group was 64 per minute and the activity heart rate was 74. The mean heart rate immediately following each of the six exercises was 88, 101, 118, 127, 154, and 165.

In the case of the first subject, exercises 4 and 5 were not performed. Subjects 3, 10, 11, and 13 to 20 were completely exhausted after the fifth exercise. Subject 14 was completely exhausted after exercise 4.

The mean leukocyte counts for the entire group of subjects for basal condition, the activity level, and after each exercise are compared graphically with the corresponding heart rate, in Fig. 1. It is quite clear that the number of leukocytes in the blood varies directly with the heart rate.

It is also important to note that subjects one to twelve inclusive are athletes in training while the remainder of the group are subjects who were definitely not in training. In the physically trained subjects the basal count is definitely lower than in the untrained group, although there is only a small difference in heart rate. It does not follow that the individual with the lowest heart rate has the lowest basal count, nor that the individual with the highest heart rate has the highest basal count. It is evident, however, that the physically untrained individuals showed

† The multiples used in counting gave groups of twenty-five. The means are rounded off to the nearest hundred.

TABLE I

THE EFFECT OF EXERCISES OF GRADED INTENSITIES ON THE LEUKOCYTE COUNT OF HEALTHY SUBJECTS. BENEATH THE COUNT IS THE CORRESPONDING PULSE RATE

Sub. No.	Basal	Normal Activity	Exercises 1	2	3	4	5	6
1	5100	5600	7900	8400	8500			10150
	50	60	70	90	100			160
2	3300	6000	7200	9350	7300	7550	10050	14600
	70	100	112	125	145	130	160	164
3	5200	8425	9225	8425	9025	9775	10000	
	60	80	100	120	148	144	150	
4	6825	9250	10275	9770	9775	9025	10350	12750
	70	90	85	90	110	117	150	168
5	6700	7500	7625	7425	7975	8725	8300	11025
	56	64	74	78	96	103	134	160
6	6900	8600	9800	10375	9925	9450	10575	16700
	70	80	100	112	136	128	152	160
7	4450	4475	6225	6450	6050	5100	6675	9025
	56	76	90	120	138	132	165	184
8	7550	6675	8375	10125	10000	10025	11700	12200
	56	60	82	92	98	111	145	158
9	6300	5425	8125	7450	8350	8250	9680	10825
	76	96	104	110	114	148	172	176
10	7900	9075	9350	11825	9775	8400	9650	
	68	62	78	87	96	138	167	
11	5325	6475	5775	7425	7600	7150	8600	
	60	62	65	80	96	115	148	
12	5700	5900	7300	10300	9650	10900	11600	11400
	55	76	74	86	88	105	147	160
13	7700	9600	11950	16325	12525	11300	11575	
	72	76	95	110	121	127	156	
14	8650	9700	12025	12100	10000	14425		
	80	90	104	116	130	156		
15	7675	8900	10875	10475	11000	10775	12475	
	72	80	98	116	125	136	156	
16	9750	10400	12650	13500	13250	13950	16675	
	72	72	106	113	140	136	156	
17	8275	7000	11425	12425	9825	9800	12000	
	54	56	72	84	98	110	140	
18	8275	8300	9700	9325	9350	10425	11575	
	64	68	90	106	145	148	160	
19	7275	8775	9400	9500	9650	11325	10600	
	50	72	75	80	95	116	150	
20	7350	7450	9800	11225	10700	9450	9150	
	66	72	97	108	134	120	160	
Mean	6810	7676	9250	10110	9511	9779	10623	12075
	64	74	88	101	118	127	154	165

approximately the same leukocyte count after the fifth exercise that the physically trained group had after the sixth exercise.

The data show that in every case except one the leukocyte count after the sixth exercise is greater than at any other time during the experiment. The data also show that the exercises caused a general tendency toward an increase in the leukocyte count although there is a tendency for the count to fluctuate.

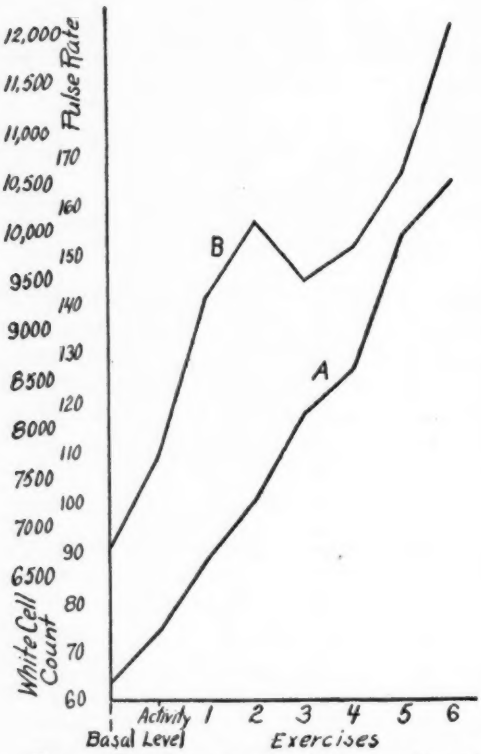

FIG. 1.—This figure is a graphic comparison of the number of leukocytes in the circulating blood with the pulse rate. The exercises on the abscissa are described in the text. Ordinate for curve *A*, pulse-rate per minute. Ordinate for curve *B*, number of leukocytes per cubic millimeter of blood.

During the course of the experiment several counts were made on a number of athletes after competitive contests including the 100-yard and 50-yard swim, and the 5-mile cross-country run. In all of the athletes investigated, their basal counts varied from 4,850 to 6,000. After the contests, the highest count recorded was 12,650, pulse 134. Among the athletes in training for competition in swimming, the highest count recorded was 9,625, pulse 150, on a basal of 5,000, pulse 72. A former athlete not in training, who was a record holder in swimming, swam 100 yards after which his white cell count was 16,925, basal 5,300. On another occasion this same athlete swam 50 yards and had a leukocyte count of 16,750. The pulse rate after the 100-yard swim was 146 per minute and after the 50-yard swim, 135.

It is obvious from the above experiments that the exercise caused an

increase in the leukocyte count which had a tendency to follow the heart-rate increase. It is of interest to note that we have never been able to find a leukocyte count of more than 18,000, while other investigators have reported much higher figures. However, in most of our experiments, physically trained athletes were used as subjects, which may explain the lower counts.

During the course of experiments involving the counting of the leukocytes, 2 counts were always made in each instance, the second count serving as a check on the first. It was noted that unless 2 successive counts were taken from the pipette without blowing out some blood between them, difficulty was experienced in getting what would be considered an acceptable check. In order to find the difficulty, an experiment was devised in which 4 consecutive counts out of the same pipette were compared. Special care was taken to mix the cells and plasma in the pipette and to observe the principles practiced in the clinic for counting leukocytes. Four consecutive counts were made out of the same pipette on 50 cases. Table II shows the data obtained. The data show the means for counts 1, 2, 3, and 4 to be 11,620 ± 275, 11,529 ± 253, 12,458 ± 300 and 12,542 ± 281. When these means are mathematically compared, the following is the result.

Count No.	*Mean difference*	*P.E. diff.*	$\frac{\text{O.D.}}{\text{P.E. diff.}}$	*Chances in 100 of a difference greater than zero*
1–2	91	374	.24	57
1–3	838	407	2.06	92
1–4	922	393	2.35	94
2–3	929	393	2.37	95
2–4	1013	378	2.64	96
3–4	84	411	.24	57

The data relative to the counting technique show that where a comparison of different counts is made, one should be consistent in the counts compared; that is, either the first or second count should be recorded or else discarded and the third and fourth count used. In some instances the differences are plus and sometimes minus. No explanation is offered for the difference. Although the differences between counts from the same pipette are small, they are consistent and should thus be recognized.

SUMMARY AND CONCLUSIONS

In order to determine the effect of exercises of graded intensity on the leukocyte counts of normal individuals, the cells were counted for twenty subjects under basal conditions, normal activity, and after six exercises of graded intensity. Also, leukocyte determinations were made on a number of athletes after strenuous exercise. The following conclusions are drawn from the data collected.

TABLE II

THIS TABLE SHOWS THE DATA RELATIVE TO FOUR CONSECUTIVE COUNTS OF LEUKOCYTES OUT OF THE SAME PIPETTE

Sample No.	Count I	Count II	Count III	Count IV
1	12850	12550	13700	14150
2	11400	11950	13200	14000
3	14800	13550	13100	16350
4	13800	13850	13600	13400
5	14500	11300	14250	15200
6	9850	10200	10950	9350
7	8300	9350	12150	10500
8	8400	8050	7250	8100
9	8600	11050	10100	9300
10	8800	8500	8350	9900
11	9100	7950	9850	9100
12	10700	10550	11400	12950
13	10050	11950	9750	10400
14	9150	10700	12650	12900
15	11550	12850	12750	11950
16	10850	11700	12800	13450
17	10100	10350	10750	10850
18	13950	14600	13700	12300
19	10600	10750	11250	11750
20	13250	12650	12750	12600
21	10500	9200	10550	10450
22	8750	9450	8150	10050
23	8700	8450	12050	10350
24	7900	7500	6650	10300
25	13900	13550	14250	13950
26	12150	10500	11850	14050
27	15400	13650	14150	15950
28	14600	14500	17900	15250
29	14550	13300	13400	13700
30	15400	17300	18050	16500
31	14150	13900	14750	12400
32	12650	11550	11650	12900
33	10350	11650	13450	12150
34	13500	15350	15500	14250
35	12450	11750	14050	14050
36	11300	11050	11800	12500
37	11500	12400	15200	13500
38	13900	12000	14350	13100
39	12450	13400	16050	15150
40	8600	9300	9750	10450
41	9500	9700	11900	12350
42	9100	9150	8850	8600
43	3850	3200	3350	3850
44	8550	6800	7150	7550
45	20200	16500	15400	18250
46	12150	13850	17150	14100
47	11600	11650	15100	15350
48	14950	15000	15950	16350
49	17950	16350	19500	20700
50	9850	10100	10700	10500
Total	581000	576450	622900	627100
A.M.	11620	11529	12458	12542
	± 275	± 253	± 300	± 281

1. Exercise, within the limits used in this study, causes an increase in the number of leukocytes in the circulating blood. This increase varies directly with the severity of the exercise.

2. The number of leukocytes in the circulating blood varies directly with the heart rate. This suggests that leukocytosis due to exercise is probably caused by the washing out of the cells from areas which tend to be stagnant, thus bringing them into the peripheral circulation. No evidence is presented relative to the possibility of inflammatory leukocytosis due to exercise.

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The Pulse-Ratio Test as a Measure of Athletic Endurance in Sprint Running

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INTRODUCTION

AT THE present time the main approach to the measure of endurance is to determine the amount of a specific task that one can efficiently perform, which gives information concerning only endurance for a specific task. The desirability of having available a method for determining endurance which is general in nature and not confined to a specific type of work prompted this investigation.

REVIEW OF THE LITERATURE

The literature dealing with tests of physical efficiency is quite extensive.[1]* Many cardio-vascular tests of a general nature have been applied to the measurement of physical efficiency. Among others, the apparent validity of the pulse-ratio test has led to its use in the investigation of general physical efficiency. However, up to the present time, no attempt has been made to use a cardio-vascular test, such as a pulse-ratio test, for measuring endurance, but the apparent success attained by others with this test seems sufficient to justify further investigation in the field of specialized sport. This the writer has attempted in the study which is here presented.

STATEMENT OF THE PROBLEM

The purpose of this investigation was to determine the possibility of substituting the pulse-ratio test for the execution of a specific type of work as a measure of endurance in the specific task in question.

In order to evaluate the pulse-ratio test as a measure of endurance in a specific task, efficiency, as measured by this test, was correlated with an endurance score in sprinting. In addition, a statistical analysis was made to ascertain how the data secured from the pulse-ratio test may best be scored for prediction of endurance in sprinting.

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* Numbers refer to bibliography at end of article.

TECHNIQUE

Two techniques were employed, viz., the determination of physical efficiency by the pulse-ratio test and the determination of an endurance index.

The Pulse-Ratio Technique.—The use of the pulse-ratio test for measuring physical efficiency has been described in detail by Tuttle,[2] and the technique thus described was adhered to in this investigation.

The Pulse Ratio Defined.—The pulse ratio expresses the relationship which exists between the resting pulse for one minute and the pulse after a known amount of standard exercise for two minutes. This relationship is found by dividing the total pulse for two minutes after the exercise by the resting pulse for one minute.

The Standard Exercise.—Various types of exercise have been employed to find one suitable for every normal individual. At present stool stepping is generally employed because a subject needs practically no training in order to step on and off a stool, and it is not too strenuous. The stool in general use is thirteen inches high and of such dimensions that steps may be conveniently executed. The stool-stepping technique is also advantageous since the severity of the exercise can be varied by changing the number of steps of exercise per minute.

The Basis for Comparing Physical Efficiency.—There are two ways available for comparing physical efficiency. One may adopt a uniform exercise and compare the resulting pulse ratios, or, on the other hand, the amount of exercise may be varied and a standard pulse ratio adopted. For the most part, the latter method is used, as was the case in this investigation.

In order to compare the physical efficiency of the same or different individuals, the number of steps of stool climbing required to produce a 2.5 pulse ratio is used as representing the efficiency of the subject.

The Determination of Efficiency.—The difficulty in determining experimentally the exact number of steps required by an individual to produce a 2.5 pulse ratio has been recently overcome by Tuttle and Wells,[3] who have devised a formula for this purpose. The physical efficiency of the subjects used in the investigation was determined in this manner.

The Endurance Index.—In order to arrive at an endurance index, the time required to sprint 60 yards was divided into the time required to sprint 220 yards. These distances were chosen because the 60-yard dash was considered to be of suitable length to test the fastest speed of the subject and at the same time not bring in the endurance factor. The average time of two 60-yard dashes was taken as the subject's speed. The 220-yard dash was selected to test endurance since it is generally agreed that this distance is long enough to tax the endurance of any individual. If these assumptions are correct, it is evident that a subject who is in good physical condition will be able to cover 220 yards at a

speed which more nearly approximates his 60-yard dash speed than one who is in poor physical condition. The truth of this assumption and the reliability of the method of arriving at an index will be shown by the data.

A Comparison of Physical Efficiency and Endurance.—The physical efficiency of the subjects studied was compared with their endurance ratio by means of correlations.

THE DATA

Data were collected on 56 subjects, 51 of whom were in training for track and 5 of whom were not. On 26 of the subjects, 18 steps were used as the light exercise and 40 steps as the strenuous. On the remaining 30 subjects, 18 steps were used as light and 45 as heavy exercise. The strenuous exercise was increased from 40 to 45 steps per minute in order to be sure that a pulse ratio greater than 2.5 would be attained, since during the training season the efficiency of the subjects might increase to a point where 40 steps would not be sufficient to yield a ratio greater than 2.5. By the use of interpolation tables, the 40-step data were made comparable to the 45-step data.

A Comparison of the Physical Efficiency Ratings and Endurance.—In order to determine the degree of relationship between the physical efficiency rating and the endurance ratings, the following correlations were computed.

	r
The endurance ratio with physical efficiency as determined from the 18 step-40 step data	$-.550 \pm .137$
The endurance ratio with physical efficiency as determined from the 18 step-45 step data	$-.497 \pm .135$
The endurance ratio with physical efficiency ratings of the whole group, 40 step changed to 45 step	$-.520 \pm .097$

A careful examination of the correlation involving the whole group showed that 9 cases were distinctly away from the regression line. An investigation of these 9 cases showed that 5 of them were the untrained subjects and 4 of them were men specializing in the distance runs. This was to be expected of the untrained subjects, but the reason for the deviation of the trained cases required further study. Observance of these men showed that each possessed some peculiarity of running stride that might cause his endurance ratio to misrepresent any data collected from the pulse-ratio test. One subject exhibited a complete tie-up of muscles when attempting any sprinting. He showed relatively high physical efficiency in that he required 38 steps for a 2.5 pulse ratio, but showed the rather high endurance ratio of 3.53. This is evidence that his tie-up slowed his 220-yard dash time sufficiently to force his endurance ratio up. Two other subjects had the tendency to pull sideways when sprint-

ing. They ranked high in physical efficiency, with 36 and 39 steps respectively for a 2.5 pulse ratio, but showed relatively high endurance ratios of 3.66 and 3.50, proving that the tendency to pull sideways slowed up their 220 time and forced the endurance ratio up. The fourth man rated poor in physical efficiency with only 21 steps required for a 2.5 ratio, but had only a moderately high endurance ratio of 3.51. This may mean that two factors may be involved, each somewhat independent of the other, health condition and athletic condition. It may mean that a man might be in poor health condition and yet have sufficient athletic condition to run a fairly strong race, thus being able to hold his endurance ratio to a nearly normal level.

Omitting the nine cases just discussed, correlations involving the same factors were calculated.

The endurance ratio with physical efficiency as determined from the 18 step-40 step data	—.914
The endurance ratio with physical efficiency as determined from the 18 step-45 step data	—.885
The endurance ratio with physical efficiency as determined from the whole group, 40 step changed to 45	—.888

As a result of this substantial difference, calculations from data involving forty-seven cases and all fifty-six cases were made separately. From this point on, data mentioned is that of forty-seven cases with forty-step data changed to forty-five-step data unless otherwise stated.

The high correlation of $-.888 \pm .031$ indicates a strong relationship between the endurance of a sprinter and his physical efficiency as determined by the pulse-ratio test.

Step Efficiency versus Other Measures as a Means of Predicting Endurance.—In order to determine whether some factor or group of factors other than the efficiency as represented by steps per minute could be used to better determine endurance, several of these were considered.

The correlation of the initial pulse rate with the endurance ratio was —.116, which indicates that little relationship exists.

The correlation of the pulse ratios resulting from 18 steps exercise with the endurance index was .693. This indicates a rather high degree of relationship but not enough to warrant substituting the pulse ratio at 18 steps for step efficiency in predicting endurance.

The correlation of the pulse ratio after 40 steps of exercise with the endurance index was —.834, which again does not warrant the substitution of this ratio for step efficiency.

The next approach was by means of partial and multiple correlations and regression equations to discover, if possible, certain factors having indirect effect on the relation of other factors in predicting endurance.

A regression equation was set up from which could be predicted the most probable endurance ratio of the subject, given his initial pulse and physical efficiency in number of steps:

Endur. Ratio = — 1.0565 (Phys. Eff. in number of steps) + .05100 (Initial Pulse Rate) + K.

The multiple correlation between actual scores and predicted scores from this equation was .8905. This group arrangement fails to show any decided advantage over step efficiency alone as an index of endurance.

In a similar manner, the multiple and partial correlations with the endurance ratio were run on initial pulse, pulse ratio at eighteen steps, and pulse ratio at forty steps, and the regression equation computed:

Endur. Ratio = .3178 (Pulse Rate at 18 steps) + .7456 (Pulse Rate at 40 steps) + K. The multiple correlation in this case was .910.

The exact relationship of scores predicted by the regression equation and scores actually obtained by the endurance test was computed, giving a correlation of .5125 for all cases and .8726 for 47 cases. This is an improvement over step efficiency alone in predicting endurance, but such a slight one as scarcely to merit the substitution.

A third arrangement was made using initial pulse rate, pulse rate at 18 steps, and pulse rate at 40 steps with the endurance ratio, giving a multiple correlation of .8420, which did not warrant the computation of a regression equation.

Since the use of these three different arrangements of variables gave no particular advantage, it was decided to use step efficiency alone for the prediction of endurance.

CONCLUSIONS

The following conclusions were drawn from the data presented:

1. There is a high correlation between the physical efficiency rating as measured by the pulse-ratio test and endurance in sprint running.
2. Physical efficiency as expressed in terms of number of steps per minute for a 2.5 pulse ratio is more reliable than any other factor or group of factors investigated as an index of physical efficiency.
3. The pulse-ratio test is a reliable criterion for endurance.
4. In employing the pulse-ratio test for practical purposes in the field, it must be remembered that judgment based on the test alone would be unfair and unreliable, as there are different levels of ability to be considered in each instance.
5. It would be advisable that a norm for each subject be established as early as possible so that deviations may be noted and compared.

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The College Freshmen's Knowledge of and Interest in Personal Hygiene*

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PART I

THE COLLEGE FRESHMEN'S KNOWLEDGE OF PERSONAL HYGIENE

HEALTH has been accepted, at least in theory, as one of the objectives of secondary education.[1]† It is also generally recognized as one of the goals of higher education. Guided by the objectives stated in the "Cardinal Principles of Secondary Education," many educators have re-examined and reorganized both curricula and content. A few schools, in order to meet the first objective, "Health," are now seriously attempting to make accessible adequate information which would favor the building of sound health habits. This instruction is occasionally given by a health course which receives a definite time allotment. In other schools it is presented through a correlation—the instruction relative to health being incorporated in various subjects in the curriculum. Certain others offer a limited amount of special instruction in personal hygiene through health talks by the school nurse or by the physician. Evidently, however, many others offer practically no instruction in this subject.

At least two fundamental questions confront those interested in the teaching of personal hygiene to college freshmen. First, is the knowledge received in this field in the secondary school sufficient to meet present day needs, or should this knowledge be supplemented by college courses? Second, where can and should one begin in the teaching of this subject?

THE PROBLEM

This study was primarily concerned with the testing of college freshmen's knowledge of personal hygiene, and with the answering of four closely related questions, as follows:

1. What high school training in health matters has been received prior to college entrance?

* This is an excerpt of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

† Numbers refer to the bibliography at end of article.

2. Do students receive through their second year in college any material amount of factual knowledge in personal hygiene?

3. Are freshman and sophomore college students influenced in their health thinking by the widespread advertising campaigns of newspapers, magazines, and radio?

4. Do freshman and sophomore college students believe the many common health fallacies and superstitions?

METHODS OF PROCEDURE

A. *Construction of a Health Knowledge Test.*—The first step in the solution of this problem was the building of an objective test to determine the students' knowledge of personal hygiene. The true-false type seemed best suited to the needs of this study. Statements of accepted and important facts relative to health were selected from ten new personal hygiene textbooks and manuals.[2-11] A list of approximately five hundred fallacies and superstitions related to personal hygiene were also gathered. Many were obtained from magazines and radio advertisements. This was supplemented by erroneous opinions expressed by students in college personal hygiene classes. Use was also made of studies relative to popular superstitions and misconceptions,[12-15] including those by Fishbein,[16,17] which were limited to matters of health. The statements were then classified under twenty-one headings and from this list a tentative trial test was built. A few questions were taken directly from the examinations repeatedly used in personal hygiene classes at the State University of Iowa.

Validation of the final test was obtained in two ways. The first was by results of trial tests. The examination was taken by 169 students. On the basis of the responses certain questions were revised, others were omitted. A second method was through the use of expert medical opinion. Through this critical examination some test items were eliminated and at the suggestion of these physicians others were added.

All the test items were then classified under their respective units, as shown in Table I. It was thought best to use four different tests of eighty items each in order that the entire field of personal hygiene might be adequately covered.

Finally, in preparing the test, the questions were so arranged that those covering the same subject matter did not follow one another too closely, and insofar as possible the more difficult were placed last.

B. *Construction of Questionnaire.*—A questionnaire was designed to serve two purposes. It was necessary first to ascertain the type and amount of health training received in high school. This was obtained in two ways. In the questionnaire the students were asked definite questions relative to their health training. Their response to these indicated the general character of the instruction available. The effectiveness of

this was ascertained by the students' knowledge of the subject as revealed by the objective test. Second, we sought to determine the students' interests in the subject of personal hygiene. The results of this study will be reported in a later section.

C. *Methods in Administering Tests and Securing a Completion of Questionnaires.*—Through the cooperation of the Men's Physical Education Department of the State University of Iowa approximately two hours were granted for the giving of this test and the answering of the questionnaire. All of the freshmen and many sophomores who were required to take physical education were in this way tested. Those taking the test were comfortably seated in a large classroom in groups of about fifty. It was found that the time allowed was ample for completing the test and the questionnaire.

D. *Groups Studied.*—This study was primarily undertaken to determine freshmen's knowledge of personal hygiene. For comparative purposes the smaller group of sophomores was also tested. The total number of students studied in this way was 764; of this number 502 were freshmen and 262 were sophomores (Table II). The freshmen came from 254 different schools, approximately one-fifth in states other than Iowa. The sophomores came from 160 different schools of which one-eighth were out of state. The results may therefore be interpreted as showing in a general way the status of health instruction in the state of Iowa.

E. *Method of Scoring and Ranking Test Items.*—All papers were scored in the manner usually used for true-false tests, i.e., by subtracting twice the number wrong plus the number omitted, from the total possible score. Individual test items were also ranked according to per cent missed and omitted, in order that various comparisons might be made.

RESULTS

A. *The Present Status of Health Education in the High Schools of Iowa.*—It is generally recognized that health education is a responsibility of all the departments in the high school. "Health knowledge comprises information from many fields of pure and applied science. The health instruction program in secondary schools is responsible for presenting this information in relation to the fields of knowledge from which it has been drawn. This can be accomplished by choosing from among the subjects generally taught in high schools those which make possible contributions to health instruction."[18]

Various subjects with which health education might be correlated were listed in the questionnaire used and instructions were given to check those taken in high school (Table III). The students were then asked to underline those subjects which included practical instruction pertaining to health (Table IV).

Table IV shows that those engaged in the teaching of physical education and athletics are meeting the health objective to a greater extent than are certain other departments in the high school. Undoubtedly a large amount of health material can be correlated with physical education, and the desire for participation in sports is one of the strongest motives for the observance of health rules. Through biology and botany information can be given as to the fundamental life processes and the existence of harmful and helpful micro-organisms. Furthermore, new scientific words should be added to the vocabulary, many of which are important for adequate health instruction. Through general science such topics as ventilation, heating, and lighting can be emphasized. If this health material is being taught through these subjects it is not recognized as such by the student.

Various methods are commonly used in the teaching of health. By the questionnaire returns the freshmen studied could be divided into four different groups according to the method of instruction used: (1) those having had only special lectures in the subject, (2) those having had a specific course with a definite time allotment, (3) those having had a hygiene course and, in addition, lectures by special speakers, and (4) those who received no apparent instruction (Table V).

Thirty-seven per cent of the freshmen studied received health instruction only through the use of special speakers. Approximately two-thirds of the topics presented in this instruction were concerned with personal health, the remaining one-third relating to public health. The personal hygiene topics used for instruction are shown ranked according to frequency in terms of per cent (Table VI). The special speakers on these various topics are shown in Table VII. Sex education, care of the teeth, and cleanliness make up over 60 per cent of the topics discussed by special speakers. Such important units as nutrition, mental health, tuberculosis, and many others apparently have received very little attention.

A comparison in health knowledge was made according to the type of instruction received (Table V). In this comparison only the freshman group was used and the results of the four examinations were combined (Table VIII).

Although some indicated that in addition to the above four methods, they had received health instruction through the correlation method, the returns were such that this type of instruction could not be taken into consideration in this group comparison. Pearson's Coefficient of Variation was computed on the above four groups, comparisons being made with Group 1, those having a specific health course plus special speakers. Those having special speakers were found to be 95.3 per cent as variable as Group 1, those having no instruction 98.5 per cent as variable as Group 1, and those having a specific health course 84.8 per cent as variable.

To obtain some idea as to the health reading by students in high school, a specific question was used in the questionnaire asking which magazines containing health articles were frequently read. Approximately 65 per cent stated that they did not regularly read in this field. Of the remaining 35 per cent, the distribution of magazines read was as follows: *Physical Culture,* 16.5 per cent; *Hygeia,* 16.3 per cent; with *Strength, Journal of Health and Physical Education, Journal of the American Medical Association, Athletic Journal, Human Body,* and articles by Royal S. Copeland making up the remaining 2 per cent.

A survey made by the United States Public Health Service in 1927 reports that 29 per cent of the schools studied attempt an integrated sex education program in high school.[19] They also found a decline of the special lecture method.

Forty-three per cent of the freshmen indicate that they had received instruction pertaining to sex while in high school. All of those answering this question gave the method used in this instruction (Table IX). This group represents forty-five different Iowa high schools. Fourteen per cent of those receiving this instruction were from other states. It will be noticed that most of the instruction was given through the special lecture method and little attempt appears to have been made to have an integrated sex education program.

Those who had received definite sex instruction with methods as shown in Table IX were compared with an equal sampling of those who had not received this instruction (Table X). The objective test used contained twenty-two questions on various phases of social hygiene. These test items were simple questions concerning the reproductive system, the venereal diseases, their control, and the relation of social to mental hygiene. The means for the two groups show no significant difference.

The variability of the two groups was further compared by computation of the coefficient of variation, with no significant difference found.

B. *A Comparison of the Freshman and Sophomore Groups in Health Knowledge on the Basis of Units.*—Figure 1 shows a comparison between these two groups in terms of per cent marked wrong (missed and omitted). Apparently there is no significant difference in health knowledge between these two groups, although the sophomores are slightly less prone to believe certain health fallacies than are the freshmen.

C. *The Status of the Freshman and Sophomore Groups in Health Knowledge on the Basis of Test Items within Units.*—Specific instruction was given to each group to omit the test questions rather than to guess. In reviewing the tests it seemed apparent that this instruction was generally followed. Questions based upon factual knowledge were commonly omitted. On the other hand, the students generally answered questions involving health superstitions, evidently believing that in these

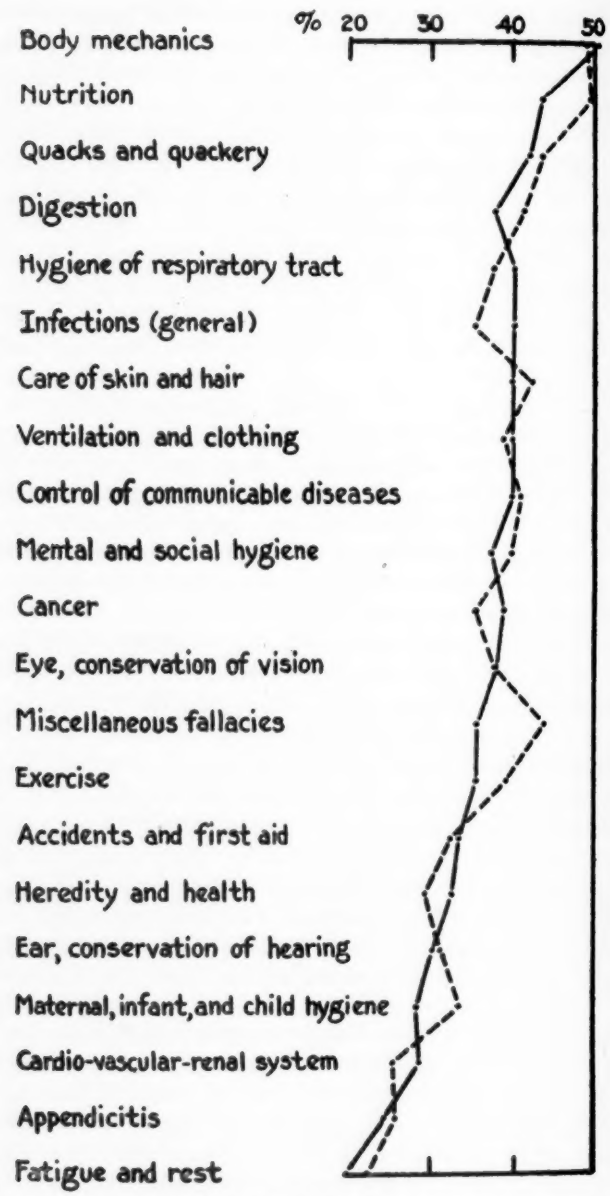

FIG. 1.—Comparison of Health Knowledge of Freshmen and Sophomores. (Based upon average per cent missed and omitted in four examinations, 764 cases.)

Sophomores ——— Ordinate in units
Freshmen - - - - - Abscissa in per cent

Average per cent missed and omitted: Freshmen 37.08; Sophomores 36.16.

their information was reliable. The omissions and the errors therefore indicated definitely that the student was not familiar with the fact covered in the test item. When the answer was correct there still remained a possibility that the student contrary to instructions may have merely guessed. It is recognized therefore that an evaluation of the student's knowledge on the basis of the errors or omission presents a more favorable picture than probably exists. The following discussion is based on the known lack of information, i.e., the number of errors or omissions.

1. *Infections (Thirty-two General Items).*—By these returns it is evident that both groups lack a clear concept as to where disease-producing organisms originate and to some extent as to how they are transferred. Sixty-two per cent of the freshmen and 72 per cent of the sophomores still believe that disease-producing organisms are spontaneously generated from filth. The names Jenner and Koch appear to mean little to either group, although in both questions the freshman percentage missed is lower. About 50 per cent of both groups apparently believe that disease may be conveyed long distances through the air, and a slightly smaller group believes that organisms cannot live within the human body without injury to this host.

Not only is a definite lack of knowledge shown in this respect, but almost two-thirds of both groups believe that the air may be cleared of impurities by the burning of smoldering leaves, and that a "frosty winter is more healthy than a mild one."

Both groups do realize, however, that milk is an excellent medium for bacterial growth, that organisms on the unbroken skin ordinarily produce no damage, and that during coughing and sneezing small particles of moisture "droplets" are expelled, which often carry disease-producing organisms.

2. *Heredity (Sixteen Items).*—Both groups show about the same ranking of questions in this unit. The belief that a mother's child before birth can be "marked" apparently still is held by many students of college rank. The fact that over 50 per cent of both groups believe tuberculosis to be inherited either implies a lack of knowledge of inheritance, or a lack of knowledge of this disease. Both groups, however, show some knowledge of this unit, as evidenced by questions covering the effect of alcoholized parents on offspring, sterilization in the improvement of the race, physical defects not always being the result of poor inheritance, and that parents, both of whom show no defects, may produce defective children.

3. *Hygiene of the Respiratory Tract (Thirty-two Items).*—Inasmuch as colds have been shown to be a leading cause of illness and of absence from school or work, and about 30 per cent of all deaths at the ages of fifteen and sixteen are due to pulmonary tuberculosis, these two items received special emphasis in this unit.

Each group shows a serious lack of knowledge of tuberculosis. Approximately one-half of the individuals in both groups do not know that the causative organism is definitely known, that rest is of importance in treatment, or that human sputum of tuberculous individuals is infective. A similar proportion do not know the value of the Mantoux test or the ages in which the infection most commonly causes death. A great many in both groups still question the fact that bovine tuberculosis can be transmitted to children through drinking raw cow's milk.

Various common fallacies in regard to colds are commonly held by both groups, as evidenced by the belief that a cold is best treated by a hard "work out" or that we should "feed a cold and starve a fever." The effect of advertisements is clearly shown by the questions covering this unit. About one-third of the sophomores and over one-half of the freshmen believe that "washing by spraying, douching, or snuffing, of the mucous membrane of the nose with a certain popular antiseptic is an effective method for the prevention of colds," while approximately two-thirds of both groups believe that "the logical and natural way to relieve head colds is to breathe a soothing vapor because this vapor penetrates air passages which other remedies cannot reach and kills cold germs." Students who otherwise may be critical in their thinking do not appear to extend this type of thinking to the field of hygiene.

4. *Mental and Social Hygiene (Thirty-six Items).*—Neither group apparently realizes that most mental disorders arise from factors not showing any physical basis underlying these abnormalities, inasmuch as 80 per cent believe the most common cause of mental ill health to be physical damage to the central nervous system. Over 75 per cent of the freshmen and a slightly smaller group of the sophomores believe insanity to be a common result of excessive masturbation. Fifty per cent of both groups question the result of self-restraint on the physical and mental health while a slightly smaller group believe any physical or mental disease can be contracted by thinking too much about it. Twenty-five per cent of the freshmen believe the natural instinct to be a perfectly trustworthy guide while only 8 per cent of the sophomore group believe this to be true.

In social hygiene there is evidently, first, a lack of knowledge as to structure and function of the reproductive system. Over 70 per cent of both groups believe the vagina to be a gland of internal secretion. Forty per cent of the freshmen and a slightly smaller group of sophomores do not know that the reproductive glands of the male produce sperms and an internal secretion which influences growth and modifies behavior.

Along with this lack in knowledge of structure and function there is a further lack in knowledge of the venereal diseases. Seventy-five per cent of both groups believe that sterility of the female by gonorrhea is brought about through an actual destruction of the egg. Approximately

one-half of the freshmen and one-third of the sophomores do not question the statement that the common skin disorder "acne" is closely associated with the venereal disease syphilis. Almost 50 per cent of both groups question the present importance of the control of syphilis as compared with tuberculosis.

5. *Nutrition (Thirty-one Items).*—Even in normal times the proper selection of foods is an important problem for the young college student. During recent times this problem has assumed still greater importance.

The possible relation of proper food selection to colds and respiratory infections is apparently a new fact to both groups, while the importance of an adequate diet to the building of sound teeth appears to be rather well known. That a diet rich in carbohydrates tends to lead to obesity is questioned by over 50 per cent of both groups, indicating either a lack of knowledge of carbohydrates or of the word "obesity." About one-third of each group do not know that milk is the best source of calcium or that the average American meal is frequently deficient in this food substance. It is not surprising that many in both groups believe whole milk to be an ideal food containing all the necessary vitamins and minerals, but that this is also believed of bread, meat, and potatoes is rather startling, even though these food substances do constitute the average American meal. Approximately 50 per cent of the freshman group believe pasteurization markedly alters the food value of milk while one-third of each group do not recognize the fact that skimmed milk is nutritious.

Again we have an interesting study of the effect of advertisements. The many advertised values of yeast are commonly accepted by both groups. They accept this product as an excellent substitute for green vegetables, believe that it strengthens the intestinal tract, and that when combined with iron is particularly effective in increasing weight.

There are apparently more health fallacies and misbeliefs in the field of nutrition than in any other unit in personal hygiene. Over 50 per cent in both groups believe fruits allowed to remain in the original container until the next meal will be poisoned; that cucumbers should be sliced and soaked in salt water to draw out the poison; that acid fruits and milk should not be eaten at the same time; and that milk is a mucous-forming food and hence is undesirable for persons inclined to be troubled with catarrh. Although these misbeliefs may not be harmful to health, yet they do show clearly a lack in knowledge of this fundamental unit.

6. *Digestion (Eight Items).*—Each group shows a lack in knowledge of the fundamental facts of digestion. They accept the statements that baking soda and chewing gums are definite aids to digestion, that certain laxatives not only stimulate the entire eliminative tract but strengthen and regulate the bowels for normal, natural functioning, and that the curdling of milk in the stomach is an indication of indigestion.

Although self-medication is widely practiced for many disorders, perhaps in no field is this practice more widespread than for disturbances of the digestive tract. The harm of self-medication and the effects of advertisements can be combatted only by a knowledge of the anatomy and physiology of the digestive organs. With this knowledge the individual is much more apt to realize that constipation is best prevented by proper habits of living and eating.

7. *Appendicitis (Five Items).*—The dangers of appendicitis can be allayed only through early recognition and surgical care. A knowledge of the common symptoms arising during an attack is important, not as a basis for diagnosis, but rather so that a physician will be consulted at once. Approximately 50 per cent of both groups do not recognize the danger of "left-sided" appendicitis, while about one-third do not know that food taken during an attack may aggravate the infection. That the common symptoms of appendicitis are fever, nausea, and vomiting and that it may easily be mistaken for "indigestion" is recognized by about one-fourth of both groups.

8. *The Ear and the Conservation of Hearing (Twelve Items).*—The chief cause of defective hearing is inflammation of the middle ear. A rather large number from both groups does not realize that "the prevention of middle ear diseases consists almost entirely of the prevention of nose and throat infection, and the immediate attention to those that do arise," or that "scarlet fever, diphtheria, and measles frequently cause an infection of the middle ear." Both groups do believe "it is a dangerous practice to introduce hard objects into the ear to remove ear wax," but do not realize the danger resulting from forceful blowing of the nose.

Again there is shown a lack in knowledge of structure. Almost 60 per cent of both groups believe "a broken ear drum always causes deafness in that ear," while approximately 25 per cent believe infection of the middle ear to be impossible. Artificial ear drums are accepted by 30 per cent of both groups as an effective method in stopping all head noises and curing deafness while a similar number do not know that "most advertised cures for deafness are worthless."

9. *Maternal, Infant, and Child Hygiene (Sixteen Items).*—Over 50 per cent of both groups accept the statements that "maternal deaths and disability are markedly decreased by a quick operative delivery," and that "mal-nourished children are seldom found in better class homes." Neither group realizes the importance of breast-feeding or the dangers of infection during childbirth, but both groups for the most part believe children should be lightly clothed with their limbs bare, so that they may become "hardened." Various other misconceptions are commonly held, such as, standardized age, height, and weight tables are always safe guides for determining a child's optimum weight, or that it is desirable for children to be fat, as they are then more likely to be healthy. Both

groups do recognize the importance of the expectant mother's diet and that infections of the infant are often acquired through the use of unsafe milk, but tend to question the value of adding orange juice and cod-liver oil to the infant's diet during the winter months.

10. *Body Mechanics (Six Items).*—Young college students are more likely to have some sort of foot defect than defects of any other part of the body except the eyes and teeth. "Flat foot" is the most common abnormality of the foot.

Each group recognizes the importance of faulty shoes as a factor in causing foot strain and weak feet, but over 60 per cent of both groups would correct weak arches by the use of arch supports, and correct round shoulders with braces. Exercises for the regaining of lost muscle strength in the correction of structural abnormalities are apparently unknown.

11. *The Eye and the Conservation of Vision (Twenty Items).*—Defective vision usually ranks next to defective teeth in studies on the incidence of physical defects. Certain eye defects are due to improper structure. Others, however, are caused by improper use of the eyes, faulty posture, unsuitable environmental conditions, and sometimes by infections. Many of the latter causes of visual defects can be prevented through a knowledge of structure and the hygienic use of the eyes.

Lack in knowledge of structure is shown by the acceptance, by over 50 per cent of both groups, of the statement that failing vision may often be arrested by appropriate eye exercises, that a permanent squint may be caused by voluntary squinting, or that the eye chart test, as used in the school examinations, reliably detects far-sightedness. Many also believe that "our modern surgeons can take the eye out, wash it, and put it back."

Almost all of the individuals in both groups recognize headache as a common symptom of eye strain and that thorough testing of the eyes requires the services of a trained physician.

Over 50 per cent of both groups do not realize that poor posture may be indicative of poor eyesight, while 45 per cent of the freshmen and 25 per cent of the sophomores think color blindness can be successfully treated. Approximately 40 per cent of both groups believe many effective cures for eye troubles are advertised in current periodicals.

12. *Exercise (Eleven Items).*—Many fallacies are commonly believed to be true by both groups in this study of exercise. Especially is this true in regard to weight reduction. Both groups fail in this respect to recognize the importance of diet, or that loss in weight after a "workout" is principally loss in moisture, while they believe also that loss of fat can be materially increased by the wearing of excessively heavy clothing.

Of more importance to general health are certain other commonly held misbeliefs. Many believe that increase in muscle and heart size is

especially beneficial to health and that well developed and large muscles increase general resistance, but about one-third of both groups fail to realize the importance of having the highly trained individual discontinue exercise gradually.

13. *Fatigue and Rest (Four Items).*—The general public always has done and always will do a certain amount of self-drugging. Dangers in this practice are obvious. Drugs used to promote sleep are especially dangerous, in that habit formation may result. One-fourth of both groups believe that certain safe and effective drugs for promoting sleep are found in general advertisements. About the same number do not realize that extreme fatigue may affect the nervous system and general health. They do recognize, however, that the amount of sleep for complete recovery from a day's work varies in different individuals, and also depends to a large extent on the type of activities engaged in.

14. *Accidents and First Aid (Four Items).*

Fainting, which frequently follows accidents, is probably the most common condition which needs first aid. About one-third of both groups do not know that fainting is a temporary anemia of the brain or that the main object in treatment is to increase circulation to the brain by placing the person in a position (head down) in order that this circulation may be restored. Although rest to the injured part is important in all sprains, 25 per cent of both groups would treat an injured ankle by walking on it, while about 60 per cent of both groups believe a nose bleed can be stopped by pressing the upper lip.

15. *Miscellaneous Fallacies (Seven Items).*—That freshman and sophomore college students do not have a sufficient background in the fields of hygiene and physiology to enable them to discriminate between the genuine and the false in the field of health and disease has been shown by previous test items and is further borne out in this unit.

Rubber girdles are accepted by over 50 per cent of both groups as a method which will materially reduce any portion of the body. A slightly smaller group believe that the blood during the winter becomes thick, causing a sluggish feeling in the spring, but that this condition can be overcome by using spring tonics which effectively thin the blood. About one-third of both groups believe that a deep tan is an indication of good health and bodily vigor, while people with ruddy complexions are believed to be particularly healthy. Highly advertised reducing cures are recognized by both groups as being either ineffective or unsafe.

16. *Control of the Communicable Diseases (Twenty-eight Items).*—The methods by which the individual and the community are protected against the communicable diseases should be common knowledge to students of college rank. This involves knowledge which may be used to prevent the spread of infection, to reduce the likelihood of exposure, and to put into practice protective immunization measures.

First, there is a lack in knowledge of the sources of these diseases. This was shown in Unit 1 (Infections) and is further borne out by the following test items. Over 75 per cent of both groups believe typhoid fever to be caused by sewer gas, while about 50 per cent of both groups do not know that the source of typhoid fever, diphtheria, and epidemic meningitis commonly is a human carrier. Approximately one-third of both groups believe infantile paralysis to be caused by a fall.

The dangers of these diseases, especially to the young, are not recognized. About 65 per cent of both groups believe it to be more dangerous for an adult than for a child to have whooping cough, and that it is better for children to have such diseases as measles, whooping cough, and chickenpox, before they reach school age.

Apparently little is known of the common diagnostic or immunization measures used. Over 60 per cent of both groups do not know that a tuberculin test with the X-ray is used in tuberculosis, or that the Shick test is used in diphtheria. Vaccination against smallpox is believed to cause "lockjaw," "blood poisoning," or symptoms that are as bad and sometimes worse than the disease itself.

17. *Quacks and Quackery (Seventeen Items).*—Freshman and sophomore groups appear as gullible to quacks and quackery as is the average individual.

Over 85 per cent of both groups believe that the spinal nerves commonly are pinched or compressed by dislocations, while a slightly smaller group believe that all nerves are distributed to the various parts of the body from the spinal cord. Fifty per cent of both groups would agree that the testimonials used are a reliable test of cults and medical practices. Apparently no information has been given to either group concerning the powers and limitations of the "National Food and Drugs Act" over the sale of "patent medicines." About one-third of each group accept widely advertised sun lamps as safe and efficient substitutes for sunlight, magnetic blankets for increasing the iron content of the blood, and violet bulbs in the ordinary light socket for the production of violet rays.

18. *Care of the Skin and Hair (Eleven Items).*—The vast bulk of cosmetics on the American market are harmless. Some, however, are potentially dangerous. These include such products as hair dyes, "freckle removers," and certain depilatories. Certainly college freshmen and sophomores should have sufficient knowledge of the care of the skin and hair to protect themselves against such fallacious advertisements.

Approximately 35 per cent of both groups believe chemical depilatories (hair removers) can dissolve excessive hair without skin injury and that certain safe commercial hair removers, as sold in beauty parlors or drug stores, will permanently remove hair. A slightly smaller group believe that moles and warts can safely be removed at home.

Certain widespread misbeliefs are commonly accepted by both groups. These include the following: that sulphur and molasses are an effective cure for impure blood; that the hairs of the head are nourished through a central cavity; and that frequent cutting of the hair causes a thicker growth.

19. *Ventilation and Clothing (Six Items).*—Proper ventilation, according to both groups, is primarily concerned with keeping the carbon dioxide content of the air below the danger point. Over 80 per cent of the freshmen and sophomores believe that the humidity of the home can be materially changed by the simple evaporation of water. The effect of high temperature and low humidity on the mucous membranes and the relation of this condition to colds and respiratory diseases is not generally recognized. The old belief that "night air is unhealthful" is not commonly held by either group.

20. *Cardio-Vascular-Renal System (Eleven Items).*—Today heart disease stands at the head of the list of the leading causes of mortality. Knowledge concerning the control of heart disease, and the other so-called "degenerative diseases," is available but apparently has not yet been brought into general use.

That a common cause of heart disease in children is damage resulting from the acute infectious diseases, that heart disease is important as a cause of death, that urinalysis is important in kidney trouble, and that hardening of the arteries causes both apoplexy and heart failure in middle or advanced age, are new facts to many in both groups. The importance of the regular health examinations and health habits in the protection of the cardio-vascular-renal system appears to be generally recognized.

21. *Cancer (Seven Items).*—A large proportion of the deaths from cancer represent a needless waste of human life. Though the exact cause of the disease is not yet established, still practical control measures which would often be effective are available. These should be common knowledge.

Approximately 60 per cent of both groups fail to realize that cancer is usually curable at some stage in its existence. About one-fourth of the freshmen and one-third of the sophomores do not know that cancer is not a blood disease nor that it is not contagious. Neither do they know that some ulcers of the stomach, if neglected and untreated over a long period of years, may turn into cancer, while about one-half of both groups believe rectal cancer to be caused by harsh irritating toilet tissue.

SUMMARY AND CONCLUSIONS

The following conclusions have been drawn from the data collected through the use of a questionnaire:

1. Apparently those engaged in the teaching of physical education

and athletics are meeting the health objective to a greater extent than are certain other departments in the high school.

2. Approximately one-third of the freshmen studied indicated that they had not had a health course nor had talks been given in this subject by special speakers.

3. Eighteen per cent of the group studied received a specific health course and talks by special speakers, while 6 per cent of the group received only a specific health course.

4. Thirty-seven per cent of the entire group had received special talks on health. In these special talks about two-thirds of the topics selected were in the field of personal hygiene, with the three units sex education, care of the teeth, and cleanliness making up over 60 per cent of the topics presented.

5. Seventy-five per cent of the special speakers on health topics are either the physician, physical educator, or nurse.

6. No significant difference was found in health knowledge when comparison was made with the type of instruction given in high school.

7. Little attempt appears to have been made to have an integrated sex education program in the schools of Iowa. Most of this instruction still is being given through the use of special speakers.

8. No significant difference in knowledge was found between those having had and those not having had sex education in high school.

9. Sixty-five per cent of the freshmen studied do not regularly read magazines containing health articles. Of those who do read in this field approximately one-half read magazines which contain unscientific health articles and fallacious advertisements.

Within the limits set by the tests used, the following conclusions appear to be justified:

1. There is no significant difference in health knowledge between freshman and sophomore college men, although the sophomore group is slightly less inclined to believe certain health fallacies.

2. There is a serious lack in knowledge of simple structure and normal functioning of the human body.

3. There is a serious lack in knowledge of hygienic facts and principles.

4. Due to the limited background in hygiene and physiology both groups are unable to discriminate between the genuine and false in advertising pertaining to health and disease.

5. The high school has failed to remove many commonly held misbeliefs and fallacies in the field of health.

RECOMMENDATIONS

In the light of the foregoing conclusions the following recommendations are made:

1. It is recommended that hygiene be taught in all high schools of Iowa either by receiving a definite time allotment, through the correlation method, or by a combination of these methods.

2. It is recommended that in the junior and senior high schools more attention be paid to health fads, fallacies, and superstitions in the selection of content.

3. It is recommended that physiology be offered in more high schools as an advanced science and that in the teaching of this subject especial attention be given to health topics.

4. It is recommended that social hygiene be taught through an integrated program rather than through the use of special speakers.

5. It is recommended that, until the high schools of Iowa adequately meet the health objective, freshmen of the University of Iowa be required to take a health education course.

PART 2

COLLEGE FRESHMAN INTERESTS IN PERSONAL HYGIENE

Present educational philosophy demands that in the selection and validation of curriculum-materials, analysis be made both of present and future needs and interests. The college undoubtedly presents many new life problems to the young student, especially during the freshman year. The college hygiene course, if it is to take its place in the curriculum, must meet the actual needs of the students, and, in meeting these needs from year to year, must be sufficiently flexible to change with these student needs. Personal hygiene, as it has been taught in our colleges, has too often failed. This may, at least in part, be due to the forcing of adult problems on the young student. Although these problems may be important, they often lack interest. Infant hygiene is to be considered as an important unit in personal hygiene. To the college freshman student, however, it is a distant and remote problem. "The genuine principle of interest is the principle of the recognized identity of the fact to be learned or the action proposed with the growing self; that it lies in the direction of the agent's own growth and is, therefore, imperiously demanded, if the agent is to be himself." [20] Ordinarily, however, the training and care of children is too distant a problem for the young student to seriously identify with self.

However, adult needs must also be considered, and from the present educational point of view present and future needs together should form one continuous development. Differences of opinion still exist concerning the extent to which present interests and needs are to influence educational procedures and content, but "all agree that its ultimate test is the effectiveness with which subsequent situations are met by the individual so educated." [21]

STATEMENT OF PROBLEM

It is the purpose of this study to determine the interests and needs of college freshman men in the subject of personal hygiene, through their evaluation of health course content. This material, together with an analysis of adult problems in this subject, should give information of value in the reorganization of college freshman personal hygiene courses.

METHOD OF PROCEDURE

A. *Construction of Questionnaire.*—The data were collected through the use of a questionnaire which was constructed in such a way that it was possible not only to obtain an evaluation of student interests, but also to make possible a comparison of these interests with the health training received in high school.

The subject, "Personal Hygiene," was first divided into twenty-three units or health problems (Table XI). In view of the findings relative to knowledge of personal hygiene, presented in Part 1, it seemed very doubtful if college freshmen could accurately evaluate these units in terms of their own interest. To add to the accuracy of this measurement, short, pertinent, descriptive paragraphs of each unit were given. The student was asked to carefully read this paragraph before evaluating the listed health problems as to relative importance and interest. Four columns were used under this heading: "Very," "Quite," "Slight," and "No." In addition to the twenty-three hygiene units, thirteen infectious diseases and six other diseases and disabilities were listed and rated (Table XI).

B. *Groups studied.*—The total number of persons so studied was 639. Of this number, 408 were freshmen and 231 sophomores. The addition of sophomores to the study made possible a comparison of interests between these two groups. All those answering the questionnaire were comfortably seated, and ample time and instruction was given to make the returns as reliable as possible.

C. *Method of Ranking Health Units.*—Inasmuch as four columns, "Very," "Quite," "Slight," and "No" were used in the rating as to relative importance and interest, the scores three, two, one, and zero were alloted to the columns in the order mentioned. This made it possible to give to each unit an "interest" score. The total score of each unit was then converted into per cent to make group comparisons possible. No other statistical procedure was used.

RESULTS

Through an evaluation by 639 freshmen and sophomores of health course content, together with various other phases of personal hygiene, the following results were obtained.

A. *Do high school courses or health lectures in personal hygiene lead to a further desire for health training in college?*

In the analysis of the returns it was found possible to divide the freshman and sophomore returns into three groups, on the basis of the health training received in high school: (1) those having had a specific health course, (2) those having had only health lectures, and (3) those having had no apparent instruction in this subject. The correlation method of instruction could not be taken into consideration in this group comparison. The above three groups were then compared with respect to desire for a specific course in college (Table XII). Those who had received only personal hygiene lectures show the greatest interest in a college course. Those having had a specific health course rank second, and those having had neither a health course nor health lectures last. Both freshman and sophomore groups show approximately the same degree of change in interest, but considering the number of cases in each group, this change is of no significance.

B. *Do those who have some knowledge of personal hygiene have a greater interest in a college course in this subject than those who lack this knowledge?*

Inasmuch as the health training received in high school apparently had little effect on the desire or lack of desire for a college course in this subject, a comparison was made with the student's knowledge of the subject. Those receiving the highest score on objective tests used in this study (Part 1), were compared with an equal number of those who received the lowest score. It was found that knowledge or lack of knowledge, as shown by these tests, had little effect on the desire for a college course. Approximately 70 per cent of both groups indicated a preference for further health training.

C. *Has the type of health training received in high school any influence on later interests in this subject?*

It might be supposed that health lectures or a specific health course received in high school would lead to more, or perhaps in some cases even less, interest in certain hygiene units. It has been shown that in the health lectures given to the freshman group, the three units sex education, care of the teeth, and cleanliness make up over 60 per cent of the topics used. Similarly, in a survey of courses of study and textbooks the statement, "We should always wash our hands before eating," was ranked first according to frequency of mention.[22] Are certain phases of personal hygiene overemphasized to such an extent that interest is decreased? This comparison could be made only on the basis of the health training received in high school.

An analysis of the freshman group (Figs. 2 and 3) will show that

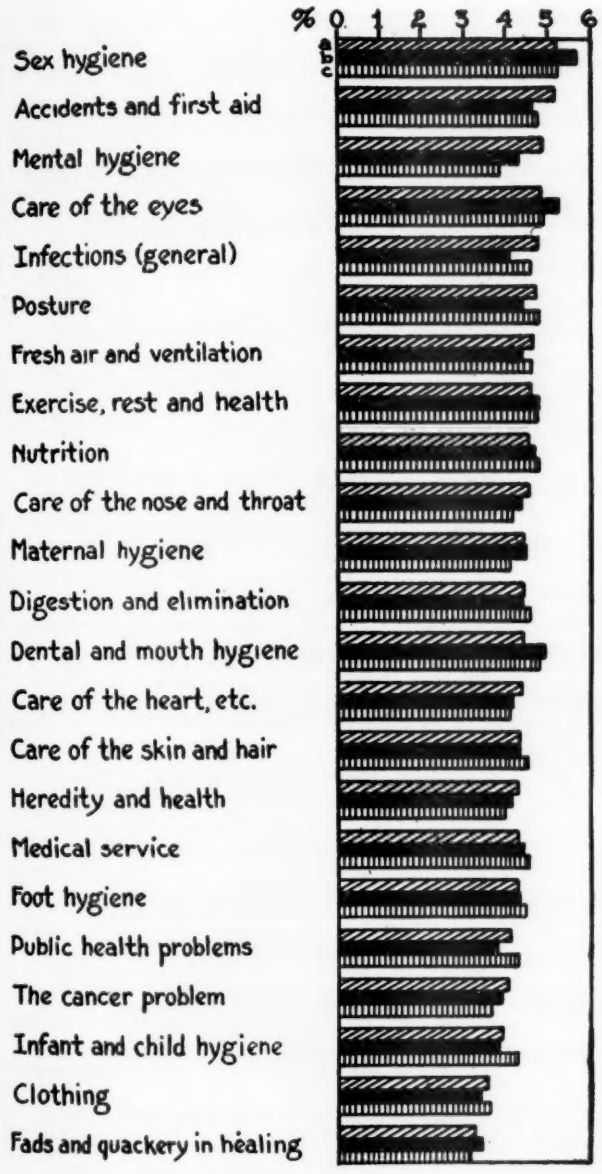

FIG. 2.—Freshman Interests in Personal Hygiene. (408 cases.) Those having had a specific health course (*a*). Those not having had health course or health lectures (*b*). Those having had lectures only (*c*). Ordinate in units. Abscissa in per cent.

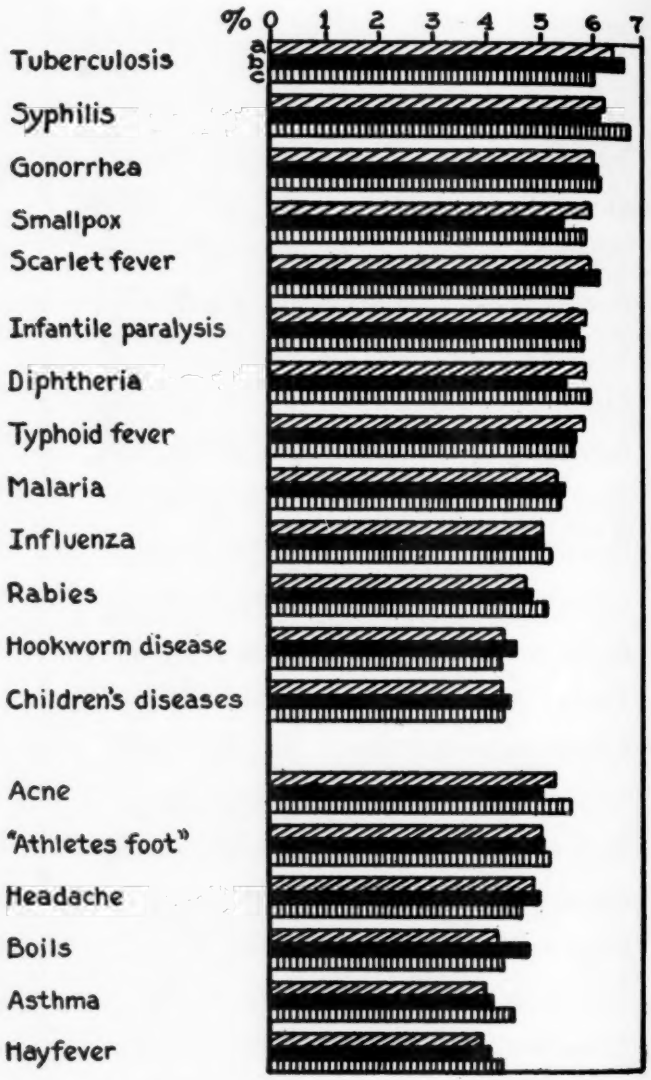

FIG. 3.—Freshman Interests in Personal Hygiene. (408 cases.) Those having had a health course (*a*). Those not having had health course or health lectures (*b*). Those having had lectures only (*c*). Ordinate in units. Abscissa in per cent.

although slight variations do occur in this comparison with health training received in high school, these differences are so small as to be quite insignificant. High school courses in health or lectures in this subject appear to neither increase nor detract from the interest in various hygiene units.

A similar comparison was made on the sophomore group, even though it was rather doubtful in view of the above results if any change in interest would be found. The results were very similar to the previous comparison.

D. *Are health interests of freshmen and sophomores significantly different?*

Inasmuch as no significant change was shown in either group in comparison with health training received in high school, these groups were combined, and freshman and sophomore interests were compared (Figs. 4 and 5).

This analysis shows that apparently no significant differences exist in health interests when a comparison is made between freshmen and sophomores, and for all practical purposes in health instruction they may be considered as one group.

E. *Analysis of freshman and sophomore interests.*

To aid in the further analysis of these units of hygiene and the various diseases and disabilities rated, two additional charts are shown (Figs. 6 and 7). In these charts the interests of freshmen and sophomores have been combined, and, to better show the degree of interest, computation is made on the basis of total possible interest score. As perhaps would be expected, those units which are concerned with immediate student problems receive for the most part the highest ranking. Such units as "Sex Hygiene," "Care of the Eyes," "Dental and Mouth Hygiene," "Accident Prevention and First Aid," are certainly of more immediate value than are units covering "Cancer," "Public Health Problems," "Infant and Child Hygiene," "Care of the Heart," etc. From the standpoint of practical use, the selection process according to interests would be to begin at the top and work down. The problem, however, is not so simple. It might be expected that certain units would be checked as very important or interesting by some but the same unit might be quite uninteresting to others. Tables XIII and XIV show a ranking of the units and diseases studied, comparison being made between two columns, "Very interested" and "No interest." The unit "Fads and Quackery in Healing" ranks last in Fig. 6 and last in the "No interest" column of Table XIII. Yet 142 individuals, or approximately 22 per cent of the individuals studied, indicate they consider this unit of great interest and importance. Apparently there are individual differ-

ences in interests that must be taken into consideration. There must, however, be some limiting of content in personal hygiene courses. From Figures 3 and 4 the units can be placed in three groups: those units and

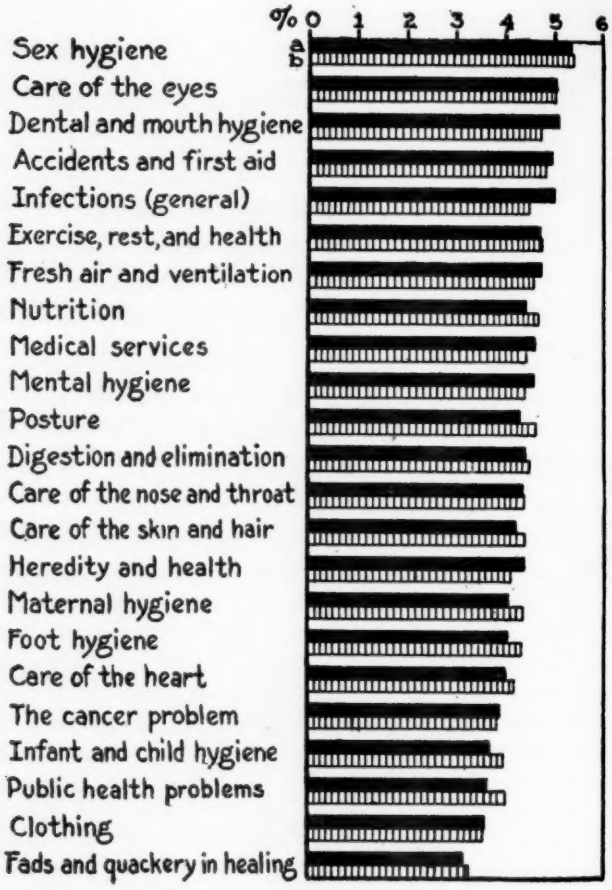

FIG. 4.—Freshman and Sophomore Interests in Personal Hygiene. Sophomore Interests (231 cases, *a*), Freshmen Interests (408 cases, *b*). Ordinate in units. Abscissa in per cent.

diseases ranking highest, those ranking lowest, and those somewhat between these two extremes (Table XV).

As this study is not concerned with the future needs of the individual, or even with the relative value of present needs, the selection of content from the standpoint of general interest would be made from the first and second columns. However, even in these units and diseases there are

individual differences shown. These individual interests can be met at least to some extent by allowing greater freedom in outside readings, reports, and term papers. Only by keeping in mind the student needs and interests and presenting material satisfying these, will effective teaching result.

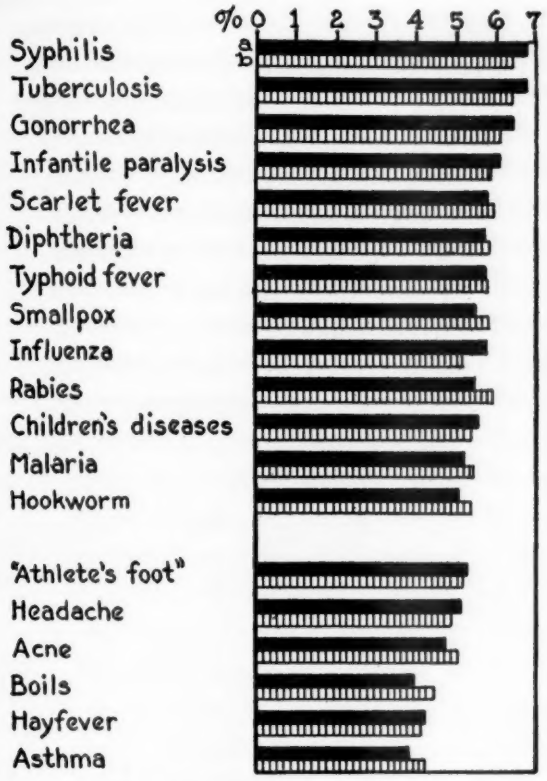

FIG. 5.—Freshman and Sophomore Interests in Personal Hygiene. Sophomore Interests (231 cases, *a*), Freshmen Interests (408 cases, *b*). Ordinate in units. Abscissa in per cent.

SUMMARY AND CONCLUSIONS

Within the limitations of a study of this nature, the following conclusions appear to be justified:

1. The type of health training received in high school has little effect on desire for further health training in college.

2. Knowledge or lack of knowledge of personal hygiene content does not add to or detract from interest in a college course.

3. Approximately 70 per cent of all groups studied are interested in a college personal hygiene course.

4. The type of health training received in high school has little effect on interests in health course content.

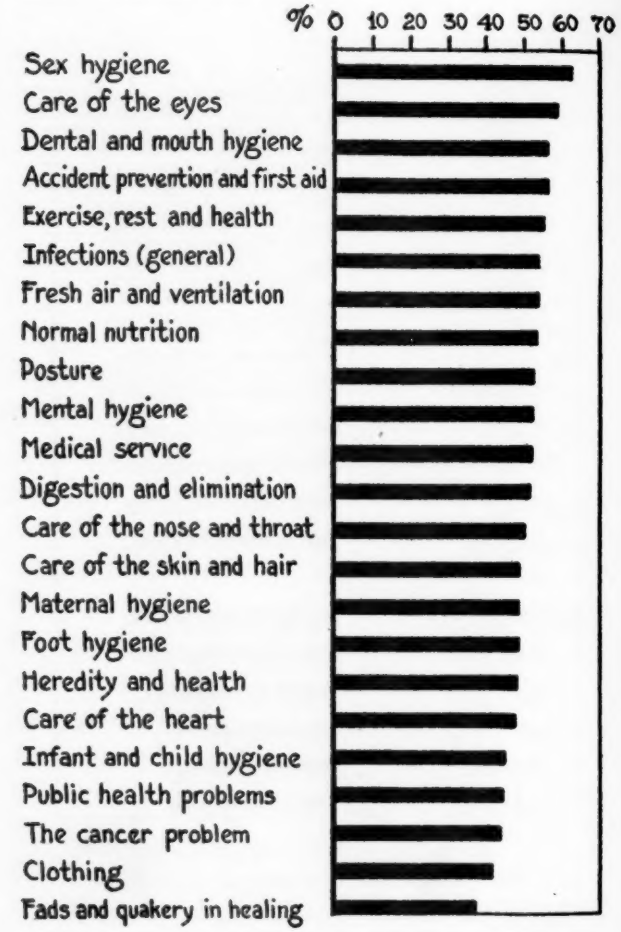

FIG. 6.—Combined Interest Ratings of Freshmen and Sophomores. (639 cases.) Ordinate in units. Abscissa in per cent.

5. In the selection of content in personal hygiene, freshmen and sophomores, as far as interests are concerned, can be considered as one group.

6. Although certain units and diseases rank high in interest as compared with others, in this consideration of student interests wide individual differences are shown.

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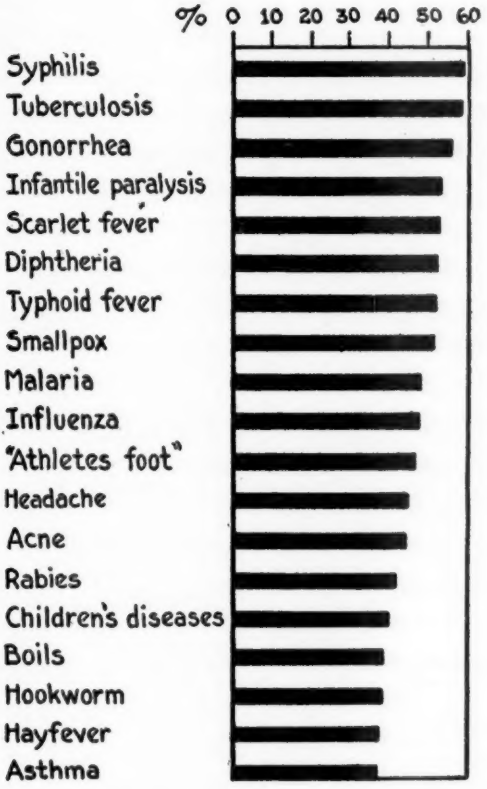

FIG. 7.—Combined Interest Ratings of Freshmen and Sophomores. (639 cases.) Ordinate in units. Abscissa in per cent.

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TABLE I

TESTS USED WITH A CLASSIFICATION OF TEST ITEMS

	Number of test items
Examination 1	
1. Infections (general)	32
2. Heredity	16
3. Hygiene of the respiratory system	32
Examination 2	
4. Mental and social hygiene	36
5. Nutrition	31
6. Digestion	8
7. Appendicitis	5
Examination 3	
8. The ear and the conservation of hearing	12
9. Maternal, infant, and child hygiene	16
10. Body mechanics	6
11. The eye and the conservation of vision	20
12. Exercise	11
13. Fatigue and rest	4
14. Accidents and first aid	4
15. Miscellaneous fallacies	7
Examination 4	
16. Control of the communicable diseases	28
17. Quacks and quackery	17
18. Care of the skin and hair	11
19. Ventilation and clothing	6
20. Cardio-vascular-renal system	11
21. Cancer	7

TABLE II

DISTRIBUTION OF CASES

Examination 1	
Freshmen	150
Sophomores	40
Examination 2	
Freshmen	164
Sophomores	37
Examination 3	
Freshmen	98
Sophomores	95
Examination 4	
Freshmen	90
Sophomores	90

Freshmen total	502
Sophomores total	262
Total number of cases	764

TABLE III

SUBJECTS TAKEN IN HIGH SCHOOL (Ranked According to Frequency of Mention)

		Per cent
1.	Physical education	79.8
2.	Physics	78.1
3.	General science	67.0
4.	Athletics	63.7
5.	Biology	42.8
6.	Chemistry	32.4
7.	Physiology	30.6
8.	Botany	7.2
9.	Nutrition	0.3
10.	Home economics	0.0

TABLE IV

SUBJECTS WHICH INCLUDED PRACTICAL INSTRUCTION PERTAINING TO HEALTH

		Per cent
1.	Physiology	64.9
2.	Physical education	58.8
3.	Athletics	40.7
4.	Biology	27.8
5.	General science	14.1
6.	Botany	7.0
7.	Chemistry	4.5
8.	Physics	2.0

TABLE V

METHODS USED IN HEALTH INSTRUCTION

		Per cent
1.	Special speakers	37.5
2.	No apparent instruction	30.0
3.	Specific course plus special speakers	18.5
4.	Specific health course	6.0

TABLE VI

PERSONAL HYGIENE TOPICS USED BY SPECIAL SPEAKERS

		Per cent
1.	Sex education	37.8
2.	Care of the teeth	13.1
3.	Cleanliness	11.4
4.	Alcohol	7.0
5.	Sanitation	5.2
6.	Tobacco	4.3
7.	Nutrition	3.5
8.	Communicable diseases	2.6
8.	Mental health	2.6
10.	First aid	1.6
10.	Diet and sleep	1.6
10.	Habit formation	1.6
10.	Tuberculosis	1.6
14.	Typhoid fever	0.8
14.	Rules of health	0.8
14.	Appendicitis	0.8
14.	Exercise	0.8

TABLE VII

SPECIAL SPEAKERS USED FOR HEALTH INSTRUCTION

		Per cent
1.	Doctor	47.5
2.	Physical educator	16.0
3.	Nurse	13.4
4.	Superintendent	6.1
5.	Principal	5.5
6.	Dentist	4.0
7.	Y.M.C.A.	2.2
7.	W.C.T.U.	2.2
9.	Red Cross	1.0
9.	Lawyer	1.0
9.	Biology department	1.0

TABLE VIII

COMPARISON IN HEALTH KNOWLEDGE ACCORDING TO TYPE OF INSTRUCTION RECEIVED

		A.M.	*S.D.*	*Cases*
1.	Specific health course plus special speakers	27.80	11.50	93
2.	Special speakers.	30.25	12.25	186
3.	No instruction..	30.80	12.05	159
4.	Specific health course	34.75	12.10	31

TABLE IX

METHODS USED IN SEX EDUCATION

Rank		*Per cent*
1.	Special talks (speaker not given)	21.5
2.	Physician	13.9
3.	Principal	7.7
3.	Personal conferences	7.7
5.	Y.M.C.A.	6.1
5.	Reading	6.1
5.	Physical education	6.1
8.	Superintendent	4.6
8.	Biology	4.6
8.	Hygiene	4.6
11.	Coach	3.0
11.	Parent	3.0
13.	Pamphlets	1.6
13.	Sunday school	1.6
13.	Scout master	1.6
13.	Priest	1.6
13.	County health officer	1.6
13.	Botany	1.6

TABLE X

COMPARISON IN KNOWLEDGE BETWEEN THOSE HAVING AND THOSE NOT HAVING SEX EDUCATION IN HIGH SCHOOL

	A.M.	*S.D.*
Those having sex education in high school.....	9.34	3.43
Those not having sex education in high school	9.76	3.47

TABLE XI

PERSONAL HYGIENE UNITS, DISEASES AND DISABILITIES USED IN INTEREST RATING

Units

1. Normal nutrition
2. Digestion and elimination
3. Dental and mouth hygiene
4. Care of the eyes
5. Care of the nose and throat
6. Care of the skin and hair
7. Exercise, rest, and health
8. Fresh air and ventilation
9. Clothing
10. Foot hygiene
11. Posture
12. Accident prevention and first aid
13. Care of the heart, blood-vessels, and kidneys
14. The cancer problem
15. Maternal hygiene
16. Infant and child care
17. Heredity and health
18. Mental hygiene
19. Sex hygiene
20. Medical services
21. Fads and quackery in healing
22. Public health problems
23. Infections—general

Control of Infectious Diseases

1. Tuberculosis
2. Influenza
3. Gonorrhea
4. Syphilis
5. Diphtheria
6. Smallpox
7. Scarlet fever
8. Infantile paralysis
9. Children's diseases
10. Typhoid fever
11. Malaria
12. Rabies (Hydrophobia)
13. Hookworm disease

Other Diseases and Disabilities

1. Headache
2. Hayfever
3. Asthma
4. Boils
5. Acne (pimples)
6. "Athlete's foot"

TABLE XII

FRESHMAN INTERESTS IN COLLEGE PERSONAL HYGIENE COURSE

	Having had personal hygiene lectures (148 cases)	Having had specific health course in high school (115 cases)	Not having had specific health course or health lectures (145 cases)
	Per cent	*Per cent*	*Per cent*
Desiring college course in personal hygiene	74.6	70.0	68.9
Not desiring college course in personal hygiene	25.4	30.0	31.1

SOPHOMORE INTERESTS IN COLLEGE PERSONAL HYGIENE COURSE

	Having had personal hygiene lectures (70 cases)	Having had specific health course in high school (73 cases)	Not having had specific health course or health lectures (88 cases)
	Per cent	*Per cent*	*Per cent*
Desiring college course in personal hygiene	75.4	72.6	68.8
Not desiring college course in personal hygiene	24.8	27.4	31.3

TABLE XIII
EVALUATION OF HEALTH COURSE CONTENT
(639 cases)

	Relative Importance and Interest			
	Very interested	*Rank*	*No interest*	*Rank*
Sex hygiene	302	1	12	6
Care of the eyes	272	2	9	1
Dental and mouth hygiene	240	3	10	2
Accident prevention and first aid	229	4	11	3
Exercise, rest, and health	225	5	20	8
Maternal hygiene	219	6	57	21
Normal nutrition	217	7	11	3
Infections (general)	212	8	16	7
Fresh air and ventilation	211	9	20	8
Digestion and elimination	211	9	11	3
Mental hygiene	205	11	29	14
Care of the heart, blood vessels, etc.	194	12	31	15
Posture	193	13	20	8
The cancer problem	192	14	70	22
Medical service	190	15	21	12
Infant and child care	186	16	63	20
Heredity and health	186	16	35	17
Care of the nose and throat	176	18	32	16
Care of the skin and hair	170	19	20	8
Foot hygiene	165	20	25	13
Public health problems	143	21	35	17
Fads and quackery in healing	142	22	126	23
Clothing	121	23	47	19

TABLE XIV
EVALUATION OF HEALTH COURSE CONTENT
(639 cases)

	Relative Importance and Interest			
	Very interested	*Rank*	*No interest*	*Rank*
Syphilis	297	1	42	7
Tuberculosis	280	2	26	5
Gonorrhea	270	3	51	11
Infantile paralysis	239	4	37	6
Typhoid fever	222	5	47	9
Diphtheria	212	6	24	3
Scarlet fever	211	7	23	2
Malaria	203	8	60	13
Smallpox	194	9	20	1
"Athlete's foot"	159	10	46	8
Influenza	152	11	26	4
Rabies	149	12	88	18
Acne	147	13	57	12
Headache	143	14	49	10
Boils	114	15	82	16
Children's diseases	113	16	62	14
Hayfever	107	17	86	17
Hookworm	107	18	74	15
Asthma	101	19	88	18

TABLE XV

GROUPING ACCORDING TO INTEREST RATING

Units		
1. Units ranking highest	2. Units ranking between extremes	3. Units ranking lowest
Sex hygiene	Infections (general)	Infant and child hygiene
Care of the eyes	Fresh air and ventilation	Public health problems
Dental and mouth hygiene	Normal nutrition	The cancer problem
Accident prevention and first aid	Posture	Clothing
Exercise, rest, and health	Mental hygiene	Fads and quackery in healing
	Medical service	
	Digestion and elimination	
	Care of the nose and throat	
	Care of the skin and hair	
	Maternal hygiene	
	Foot hygiene	
	Heredity and health	
	Care of the heart	
DISEASES AND DISABILITIES		
1. Ranking highest	2. Ranking between extremes	3. Ranking lowest
Syphilis	Infantile paralysis	Acne
Tuberculosis	Scarlet fever	Rabies
Gonorrhea	Diphtheria	Children's diseases
	Typhoid fever	Boils
	Smallpox	Hookworm
	Malaria	Hayfever
	Influenza	Asthma
	"Athlete's foot"	
	Headache	

An Analytical Study of Strength Tests Using the Universal Dynamometer

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A REVIEW of the history of strength testing reveals the interesting fact that measures of strength have been employed to meet many divergent needs. McCloy [1]* in a recent publication has pointed out that strength tests have two important uses in the program of physical education; first, as indices of health or general physical condition, and, second, as predictors of potential general motor ability or potential general athletic ability.

The revival of the Intercollegiate Strength Test[2] by Rogers[3] and subsequent refinements in its computation by McCloy[4] started a series of investigations designed to validate this battery of strength measurements for specific needs. Chamberlain and Smiley[5] showed that the Physical Fitness Index suggested by Rogers was a valid index of functional health, and Rogers[6] tried to show that grip strength was a valuable index of physical condition. Studies by Wells,[7] Kistler,[8] Handy,[9] Dunder,[10] Rump,[11] and others, were made to validate the Intercollegiate Strength Test as a predictive measure of general motor ability, general athletic ability, and classification.

The strange thing about these studies is that every investigator employed the same measures of strength, namely, those set up by Sargent over fifty years ago, which he called "The Intercollegiate Strength Test." Rump added the strength of the thigh flexors, thereby increasing the predictive value, but this was the only departure from the items in the original test. McCloy demonstrated the apparent relative unimportance of back and leg strengths and the great importance of arm strength in predicting motor ability, athletic ability, and classification.

The investigations of Rogers, and Chamberlain and Smiley, indicate that strength tests are valid indices of functional health or physical condition, but neither study proved conclusively that the muscle groups involved are the most reliable for prediction purposes. The inference drawn is that total strength is an accurate index of physical fitness and that batteries of strength tests are reliable for this purpose to the extent of their predictive value of total strength. With this idea in mind the investigation herein reported was carried out.

* Numbers refer to bibliography at end of article.

STATEMENT OF THE PROBLEM

The first purpose of this study is to analyze statistically a large battery of strength measurements to determine for each sex the muscle groups that are the most valuable for predicting total strength. The second purpose is to construct for each sex a short battery of tests which do not require expensive apparatus and which will predict total strength with a fairly high degree of reliability.

THE PROCEDURE

The strengths of 47 different muscle groups were obtained on 474 men and women by means of the Universal Dynamometer.[12, 13] The sum of these 47 measurements was then computed for each individual. This total represents a highly reliable estimate of the total strength of the individual and was used as the criterion for this study.

Of the forty-seven muscle groups tested, twenty-one were selected for analysis on the basis of major importance in physical activity. For each sex, every measure was then correlated with total strength and with each of the other twenty measurements. With this correlation matrix as a foundation, multiple regressions were computed to find combinations which would give high correlations with total strength. The general procedure followed was to select those items which gave high correlations with the criterion and low intercorrelations. A combination which closely approximates the major muscle groups tested by the Intercollegiate Strength Test was also used in order that comparative evaluations could be made. Regression coefficients in standard form † for the test scores were compared to determine the relative predictive value of each muscle group in the various combinations.

ANALYSIS OF DATA

The Intercollegiate Strength Test.—Anatomical analysis of the testing procedures resulted in a list of eight major muscle groups which are measured by this battery of tests. This list of eight muscle groups appears in Table I, accompanied by the regression coefficients and multiple correlations for each sex. The investigation by Rump indicated that the thigh flexors could be profitably included in strength testing so this group was also added to the list.

Examination of the regression coefficients reveals the 3 muscle groups which predominate in the men's test: the pectoralis major, the thigh extensors, and the leg extensors. This combination correlates .930 with total strength, indicating that these 3 muscle groups are the most valuable for predicting total strength in men. The other 5 muscle groups are of small and about equal predictive value and could without a doubt be replaced profitably by other muscle groups not included in the test.

† The coefficients in this form are generally accepted as approximations of the relative predictive value of the item.

Addition of the thigh flexors does not raise the correlation materially, probably because the thigh extensors are so highly correlated with them. They do show a predictive value equal to that of all but the predominating strengths and would probably rate much higher if the thigh extensors were omitted.

Analysis of the women's test reveals the thigh extensors as the only

TABLE I

A List of the Major Muscle Groups Measured by the Intercollegiate Strength Test Showing Relative Predictive Importance of Each and Multiple Correlation of the Complete Battery with Total Strength

Muscle Groups	Regression Coefficients			
	Men		*Women*	
1. Pectoralis Major	.251	.234	.211	.192
2. Thigh Extensors	.291	.241	.318	.168
3. Leg Extensors	.200	.172	.145	.125
4. Hand Flexors	.105	.105	.197	.176
5. Posterior Trunk	.095	.088	.188	.174
6. Latissimus Dorsi	.094	.091	.169	.145
7. Arm Flexors	.080	.083	.041	.029
8. Arm Extensors	.059	.061	.034	.040
9. Thigh Flexors	...	.100	...	.262
$R =$	.950	.952	.933	.947

predominating group when the battery does not include the thigh flexors. The addition of this group raises the multiple correlation quite noticeably, indicating that it is very valuable. The importance of the thigh extensors decreases noticeably with this addition so that it no longer is the most valuable. The remaining groups, with the exception of the arm strengths, are of approximately equal value in predicting total strength in women.

The apparent unimportance of arm strength in no way detracts from the value of chinning and dipping because several of the more important muscle groups are used in these activities.

COMBINATION FOR MEN

The foregoing analysis indicates that the muscle groups measured by testing procedures commonly employed at the present time are not of equal predictive value and that some of the measures are of little importance for predicting total strength. This leads to the assumption that a smaller battery of more carefully selected tests would prove almost as reliable and more economical. The following list presents six muscle groups whose strengths when properly combined give the best prediction of total strength of men.

1. Thigh Extensors
2. Leg Extensors
3. Pectoralis Major
4. Arm Flexors
5. Anterior Trunk
6. Foot Extensors

The multiple correlation of this battery of strengths against total strength is .956, which is slightly greater than that obtained for the 9 major muscle groups tested by the Intercollegiate Strength Test. Experimentation has shown that the thigh extensor, foot extensor, and anterior trunk muscles offer measurement difficulties which necessitate special apparatus, and consequently this combination cannot be accepted as an ideal battery of tests except in situations where this apparatus is available.

The following shorter battery is almost as reliable and is recommended on the basis of economy of time and expense, which is always an important consideration in the selection of tests.

1. Thigh Flexors
2. Leg Extensors
3. Arm Flexors
4. Pectoralis Major

This battery correlates .933 with total strength and the weighting of each measure is approximately the same; the sum of the 4 strengths therefore gives a fairly reliable total strength score. The muscle groups are all quite easily measured with an ordinary spring scale by the Martin resistance technique.[14] The author is conducting further research to standardize measurement techniques and to establish the validity of this battery; the results of this research will be published at a later date.

A COMBINATION FOR WOMEN

Analysis of the data on women resulted in the selection of the following battery of strength measurements.

1. Thigh Flexors ..... x 7
2. Thigh Extensors ..... x 5
3. Leg Extensors ..... x 3
4. Pectoralis Major ..... x 7
5. Deltoids XII
6. Hand Flexors ..... x 7

The multiple correlation with total strength of this battery of strengths weighted as shown is .938. It should be noted that a larger battery of measurements is necessary to predict total strength of women with the same reliability as for men. This is due to several factors; first, the zero-order correlations with the criterion are not as large as for men, and second, only one strength measure shows high predictive value in the women's test, whereas, in the men's test 3 groups were found to rate very high. In other words, the majority of the items in the women's test that correlate well with the criterion are also highly intercorrelated and consequently combinations of them have almost no additional value for predictive purposes. All but the hand flexors can be measured by the Martin resistance technique. Omission of this group lowers the correlation to .927 when the same weighting is used for the other five.

Further study for standardizing measurement techniques for the women's battery will also be made in the near future.

CONCLUSIONS

1. The sum of the strengths of four muscle groups—the thigh flexors, the leg extensors, the arm flexors, and the pectoralis major—gives a highly reliable prediction of total strength of men.

2. The strengths of six muscle groups—the thigh extensors, the thigh flexors, the leg extensors, the deltoids, the pectoralis major, and the hand flexors—when properly combined will predict total strength of women with approximately the same degree of reliability as the men's battery does for men.

3. The above batteries are almost as valuable for the prediction of total strength as the entire Intercollegiate Strength Test and have the added advantage of requiring no expensive apparatus.

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Individual Differences in Interests and Efforts of College Women as Related to a Program of Physical Education

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INTRODUCTION

ONE of the special problems of the physical educator is to give the student instruction in the activities in which he is most interested, for which he is best adapted, and which will have the most carry-over value for use after he has finished school.

We are realizing more and more the necessity for recognizing the wide variety of likes and dislikes of individuals. In the past our program planning has been based mainly upon the activities with which the teacher is acquainted rather than upon those things in which the pupil is most interested or to which he is best adapted. Much of this faulty program construction is due to the fact that many of the large college and university departments of physical education give the teacher training in how to organize and direct a program based on almost ideal facilities, but often fail to prepare the student teacher to make satisfactory adaptations to more unfavorable conditions. Perhaps another reason for our faulty selection of programs is that we do not know what will be most interesting to the pupil at the present and also most valuable to him in the future. In this study we attempted to find what the differences were in interests, efforts, abilities, likes, and dislikes of college women. It is hoped that these findings will be valuable in helping to plan an adequate program of physical education for women.

PROCEDURE

A questionnaire was used to secure the data. Three hundred questionnaires were given to the women in physical education classes in a small college and in a university, both of which were located in Indiana. Of the 300 questionnaires, 11 were rejected because of incomplete answers. Of the 289 remaining, 153 of the girls were freshmen, 113 sophomores, 13 juniors, and 10 seniors. The entire group included only 17 (or 6 per cent) physical education majors and 12 (or 4 per cent) physical education minors. The ages of the girls answering the ques-

tionnaire ranged from 16 to 22. One whole physical education period was given to the girls in which to answer the questionnaire.

The results are given in terms of percentages for the entire group answering the questionnaire. In some cases the total per cent for a group may be less than one hundred. The reason for this is that in several cases many did not check each item and others crossed out activities with which they were unfamiliar. Any percentage under .5 is indicated by an asterisk and over .5 per cent is considered as 1 per cent.

INTERPRETATIONS OF PERCENTAGES

(For the Whole Group Answering the Questionnaire)

Activity Preferences.—The following table gives the results for one part of the questionnaire in terms of percentages for the whole group of 289 girls. The activities were divided into 4 groups as: fall, winter, spring, and unclassified, according to their usual classification. Sections taken directly from the questionnaire are enclosed within quotation marks. (See Table I.)

"Read the following list of physical education activities. Be sure to check each activity that you know in one of the four columns. If you do not know what the activity is, cross it out."

The figures in the last column to the right indicate the manner in which the entire list of activities ranked when the percentages for the three choices were added. This ranking resulted from the following instructions. "Glance back through column one of the activity, list and mark the fall activity you like best with F1, your second and third choices F2 and F3 respectively. Likewise the winter, spring, and unclassified activities mark with W1, 2, and 3; S1, 2, and 3; and U1, 2, and 3 respectively. Unclassified activities are those activities that may be used at any time during the year provided the equipment is available."

From the results of this question we see that individual sports receive high percentages for enjoyment while team games and formal activities receive relatively low percentages. These results seem to be due to the fact that most of the girls who attend the larger institution are from homes that give the opportunity for engaging in swimming, golf, canoeing, tennis, and other sports of this nature. A large majority of these girls attend summer camps or summer resorts which offer splendid opportunity for practice in such activities.* (See Table II.)

When the first column, dealing with present participation, is considered we see that individual activities take a definite lead when the percentages for individual sports are compared with those for team games. In considering the next two columns the majority of the girls would like to "engage in" and would like "specific coaching" in individual activities. It is noticeable that the preferred activities, and those

* This information was received from the department head of this institution.

of present participation, are, for the most part, generally available to the adult population and therefore offer training for constructive leisure-time activity. If the figures for the "present participation" column and

TABLE I

	Enjoy or would enjoy very much (%) *R*	*Would like a little of this but not much* (%) *R*	*Indifferent to this activity* (%) *R*	*Actively dislike this activity* (%) *R*
Fall Activities				
Canoeing	69–3	18	8	1
Rowing	58–8	29–4	7	2
Soccer	28	30–3	26	6
Swimming	80–2	15	4	1
Volleyball	53–11	29–5	13	4
Winter Activities				
Basketball	60–5	22	11	6
Clog dancing	55–10	22	14	7
Handball	12	27–8	35–1	11
Ice skating	59–6	18	18	3
Mat exercises	17	20	27–9	29–2
Natural dancing	30	22	23	19–9
Spring Activities				
Archery	49–13	27–7	16	4
Baseball (indoor)	37	25	19	16
Baseball (outdoor)	48–14	28–6	12	11
Hit-pin baseball	3	8	22	9
Hockey	31	24	24	8
Horseshoes	20	25–11	33–3	19–10
Speedball	29	20	29–6	12
Tennis	96–1	3	1	1
Track and field	30	31–2	17	22
Unclassified				
Apparatus	17	20	18	24–5
Bicycling	52–12	20	20	6
Calisthenics	14	22	23	23–6
Danish gymnastics	10	17	20	18
Diving	43–16	21	16–4	12
Dumbbells	9	19	31	34–1
Fundamentals	6	20	24	18
Golf	58–7	20	16	3
Group games	20	34–1	26	18
Gymnastic dancing	21	24	27–9	20–7
Hiking	58–9	27–8	10	4
Indian clubs	8	20	34–2	19–8
Kickball	11	19	29	11
Life saving	45–15	25–10	21	8
Marching	18	20	30–5	27–4
Ring tennis	14	17	19	8
Roller skating	64–4	20	10	4
Wand exercises	3	15	29–6	29–3

the column where the girls say they would like "specific coaching" are compared, it is seen that the girls would like "specific coaching" in many of the activities in which they say they now take part. From this it would seem that the girls definitely want to become much better

skilled in the types of activities that they enjoy and in which they participate, or that they do not get as thorough training in such activities in the regular physical education classes as they desire.

TABLE II

	I participate in this activity during its season (%) *R*	*If a class for this activity were organized I would enroll* (%) *R*	*I should like specific coaching in this activity* (%) *R*
Fall Activities			
Canoeing	33	53–1	22–8
Rowing	44–7	42–3	14
Soccer	35–10	19	15
Swimming	61–1	28–10	33–4
Volleyball	59–2	26–12	14
Winter Activities			
Basketball	59–3	18	22–9
Clog dancing	34–11	26–12	31–5
Handball	10	13	15
Ice skating	28	43–2	23–7
Mat exercises	8	14	14
Natural dancing	12	22	20–11
Spring Activities			
Archery	30–15	29–9	27–6
Baseball (indoor)	43–8	11	14
Baseball (outdoor)	54–4	16	15
Hit-pin baseball	1	2	8
Hockey	27	25–14	18
Horseshoes	18	19	13
Speedball	32–12	12	12
Tennis	57–6	36–6	36–3
Track and field	19	21	20–10
Unclassified			
Apparatus	3	13	15
Bicycling	31–14	39–5	10
Calisthenics	7	12	15
Danish gymnastics	8	11	12
Diving	32–13	30–7	43–1
Dumbbells	1	7	1
Fundamentals	9	3	2
Golf	28	41–4	40–2
Group games	20	12	4
Gymnastic dancing	8	17	9
Hiking	42–9	23–15	1
Indian clubs	3	12	2
Kickball	7	14	3
Life saving	17	30–8	4
Marching	7	13	3
Ring tennis	8	13	3
Roller skating	54–4	27–11	4
Wand exercises	*	7	1

Reasons for Joining an Athletic Club.—No section of the questionnaire showed more interesting results than did the one on "reasons for joining" an athletic club. Twenty-five reasons were listed and the girls

were asked to check from this list the reasons why they would join such a club.

"If you had an opportunity to join an athletic club which had all kinds of equipment and instructors, for what reasons would you join? Check those in which you are definitely interested."

(The inclusion of this part of the questionnaire in such a study may be questioned. However, most of the items in other parts of the questionnaire have a direct relationship to the girls' work in physical education at the present. They are so thoroughly engrossed in this type of college environment that their judgment may be biased by many factors. They may like one teacher better than another; they may be better skilled in some activities than in others; the time of day at which the class meets and the surroundings in general often have quite an influence on the girls' attitude toward the activity. Now, if some seemingly unrelated questions can be asked that will draw the girl out of the realm of her college physical education, and get her to think in terms of the outside, this will probably result in a better means of checking her judgment in answering other parts of the questionnaire. For example, many of the reasons given below are of a social nature and the girls check most of them as important reasons for joining an athletic club. Practically the same questions were asked in one part of the original study and because the college girl has such a biased idea of the meaning of "social," as interpreted by the public, she did not recognize such a term as "to make friends" as a social quality. The mental picture in thinking of a situation in which one would join an athletic club and in which one would participate in a regular college physical education class is so much different that the girls evidently did not realize that the content of both programs would probably be very similar. Therefore, in the final check, it is quite interesting to note how closely the results coincide with each other in spite of the fact that the girls feel a very wide difference in reasons for taking part in the two different situations.)

The figures in the last column to the right indicate the manner in which the entire list of reasons ranked, when the percentages for all three were added, according to the following instructions: "Glance back over the items you have just checked and mark the one most important reason with a figure 1, the second with a 2, and the third with a 3."

We see from Table III that the most important reason for joining an athletic club is for "pleasure and enjoyment," which is purely a social reason. Such items as "because of friends," "dancing," "to meet people," and social activities in general were checked by 52 to 75 per cent of the girls. From this we see that, on the whole, the athletic club takes on more of the social, get-together aspect than does the purely physical education activity. The girls would join an athletic club mainly for enjoyment, to meet friends, or for other social purposes, while most of

the girls in physical education take it for enjoyment and not for social purposes. But when the reasons for both are carefully analyzed they convey about the same meaning.

The question raised here is whether we should have a place in our programs and in our gymnasia to provide for purely optional, socializing activities; a place for our students and others who wish to participate in

TABLE III

	Whole Group (%) *R*	*First Choice* (%) *R*	*Second Choice* (%) *R*	*Third Choice* (%) *R*	*Rank of Choices*
A good place to read	30	1	1	1	
Apparatus work	14	*	*	0	
Athletic competition	31	4	2	3	
Baseball	28	2	2	1	
Basketball	42	2	3	1	
Because of friends	75	8	8	9	4
Calisthenics	18	*	*	1	
Dancing (social and otherwise)	75	4	6	8	6
Debates and discussions	16	0	*	1	
Educational classes (theory)	16	*	1	3	
For pleasure or enjoyment	78	22	11	11	1
Golf	45	7	4	3	9
Gymnasium classes	16	*	*	1	
Handball	7	0	0	0	
Hockey	17	1	1	1	
Recreational purposes	58	8	10	8	3
Rowing	40	*	*	1	
Soccer	15	0	0	0	
Social activities	52	3	2	9	10
Swimming	76	10	8	9	2
Tennis	72	3	10	4	7
To improve health	51	3	11	6	5
To meet people	60	4	4	7	8
Track and field athletics	16	1	0	*	
Volleyball	27	*	0	1	

such types of recreation when they so desire. If this were true an entirely different meaning might be attached to the word "gymnasium."

Athletic Self-Rating.—Five degrees of athletic ability were listed and the girls asked to rate themselves accordingly.

"How would you rate yourself in all round athletic ability in all sports and all activities in the physical education program? Check one."

	Whole Group *N* (%)
Above average	49–17
Average	170–59
Below average	69–24

In constructing this part of the questionnaire the modesty of the girl in ranking herself in the top category was anticipated. For this reason five degrees of ability were listed. In computing the percentages the two upper and the two lower categories were combined, which ac-

counts for having only three groups above. The percentages for the highest and the lowest ratings were quite misleading due to the fact that only a few girls checked in either case.

The findings here show what might be expected from a group with so few majors in physical education. They check slightly more toward the lower or poorer end of the rating scale. The majority felt that they were about "average" in ability. Few checked that they were above average, and only 4 girls, of the 289, rated themselves as "exceptionally good" which was originally the highest rating point. Twelve girls rated themselves as "very poor" which was originally the lowest rating point. This grouping is close to a normal distribution of abilities.

Magazine Reading List.—A list of fifteen publications including books, magazines, and newspaper sports page were listed and the girls asked to check the ones they read fairly regularly. The group was asked to check this list of readings to determine the reading interests of a group which included only a few girls who would be interested from a professional standpoint.

"Check the following magazines or books that you read fairly regularly."

	(%) *R*
1. *American Physical Education Review*	6-13
2. Articles and Books on Health	22-7
3. *Athletic Journal*	12-10
4. *Baseball Magazine*	4-14
5. *Hygeia*	67-1
6. *Journal of Health and Physical Education*	11-12
7. *Mind and Body*	13-8
8. Newspaper sports page	65-2
9. Novels and fiction on sport	51-3
10. *Physical Culture Magazine*	31-5
11. *Sporting Page Magazine*	13-8
12. *Theater Arts Monthly*	26-6
13. *The Coach*	2-15
14. *The Dance Magazine*	12-11
15. *The Sportswoman*	31-4

The table itself is fairly self-explanatory. However, it is encouraging to note the wide reading interest in this type of material from this group. It may be surprising to notice that so many of the girls read *Hygeia* magazine, however it is readily available to the girls in both schools. Other publications that both schools offer to the students are numbers six, eight, nine, twelve, and fifteen.

This information may be suggestive to physical education teachers to encourage even a wider reading range and a greater interest by having such materials easily accessible to the girls.

GENERAL DISCUSSION OF FINDINGS

The findings from this study should be a fair representation of the preferences and attitudes toward physical education of the girls who

comprise the majority of our college physical education classes. As was stated previously, only a very few girls in this group studied were interested professionally in physical education. Hence, the results should not be skewed by the interests of so few physical education majors and minors.

It is quite noticeable throughout the entire study that the individual sports, which make such excellent recreation for all ages, are rated very highly by a large majority of the girls. This information should be gratifying to those who have supported the theory of "carry-over" value of activities into adult life.

Since the study was made in two institutions, there is not a true picture of many activities for either school, but it shows the combined interests of the two schools. In a check-up with the department heads of the two schools after the study was made, such details as these were learned: at one institution roller skating is traditional while hiking is at the other; at one school the Women's Athletic Association sponsors a Bicycling Club; picnicking is quite popular in the other school. The larger school has had speedball only one year, no hockey, only a little soccer, no gymnastics or formal work of any kind, no horseshoes, only a very little handball, and very little interpretative dancing. The smaller school has hockey, soccer, some formal work, no handball for three or four years, and very little is done with horseshoes. The larger school draws most of its girls from the larger cities and from a rather wealthy class of people who have opportunities to engage in such activities as golf, swimming, tennis, and other sports of this nature at summer camps and summer resorts.

When we understand the lack of emphasis that is put upon the team games in comparison to the much greater emphasis that is placed upon individual sports it is not difficult to see why team sports are given such a low rating. The improved skill in individual sports, due to the opportunities mentioned above, probably has some influence upon the girls' attitude toward the two types of activities.

Another interesting feature shown is the surprising indifference to all types of rhythm work. In one institution interpretative dancing is not taught and it is offered only as an elective in the other school. However, clog dancing is offered in both schools and both instructors of clogging are very capable in this type of rhythm. Nevertheless, clogging is given quite a low rating by the girls in the study. It is possible that the girls construe the terms "clogging" and "tapping" to be entirely different activities while in the physical education program we generally think of clogging as a combination of character and tap dancing rather than as an isolated form of rhythm by itself.

It is encouraging to note the wide and comparatively deep interest shown in so many physical education activities. The interest shown in

this study may be influenced by certain situations in each of the two schools. One of the schools is located in a small town and the students must furnish their own amusements with the college facilities since the town offers little or nothing of this sort. Intramural sports programs are carried on in both the women's and men's departments. Great interest is taken in the tournaments, especially by fraternal groups. The other school is located in a larger town, but there is great competition among fraternal and other organizations. Almost every drive or campaign of any sort develops into an "inter" competitive affair among the various groups.

Whatever the reasons may be, the girls have expressed a real liking and much interest in almost all forms of activities listed. This may be due to the swing of the American woman toward the vigorous outdoor life and the freedom of dress of today. But now is the time for physical education teachers to capitalize on this splendid set-up and to develop a real interest in such activities that will carry over after the "fad" for them has diminished.

SUMMARY AND CONCLUSIONS

1. A very decided partiality is shown in every check list in the study for individual as opposed to team games. This is probably the result of increased opportunity for practice in such individual activities during summer vacations. Individual types of play are much more readily accessible to most individuals than forms of team play.

2. All types of formal work received a very low rating. The question raised here is whether we should omit this type of activity from the program entirely or whether it should be retained for the girl who does enjoy such work. Our opinion is that we probably should place more stress in our college programs on exercises that could be used by the person who works in an office or does other confining work.

3. There is an extremely wide interest shown throughout the study. All types of activities find some girls who enjoy participation in such. This is in accord with what we know of the psychology of individual differences in other fields, and would probably indicate that there should be a much wider range of choice in activities in the physical education program.

4. Girls feel generally that they are not aided, but rather hindered, socially by participation in physical education. However, this belief is gradually being broken down as the physical education major adjusts herself more readily to situations outside her own field. According to this study the girls would join an athletic club almost entirely for social reasons. If the most important reason for joining an athletic club is a social one and girls in general feel they are not aided socially by participation in college physical education groups, then what is it that the

physical education set-up lacks that would include this social feature in its program?

5. There is a very wide interest shown in physical education, health education, and sports magazines. Perhaps there is an interest here we have overlooked. Hence we should have such magazines available for the girls at all times.

6. The students are asking for "specific coaching" in practically the same activities that they say they enjoy most and in which they participate most. From this it would seem that we should strengthen our teaching of technique. To do this it is not necessary to do coaching to the extreme, as the varsity coach does with his squad, but we can at least take some pointers from his type of procedure.

Leisure-Time Activities of Business and Professional Men in Iowa

By Fred E. Cameron
Vinton High School, Vinton, Iowa

THE PURPOSE of this study was to find what the average business and professional men of Iowa were doing and thinking in the way of sports, games, and other physical activities. From this cross-section view we hoped to be able to construct the college and high school curriculum of physical education which would have the greatest carry-over value for the graduate.

PROCEDURE

Approximately one thousand questionnaires were sent out to business and professional men in various Iowa towns. Such items as age, occupation, high school or college graduate, married, etc. were asked for, and sixty-six activities, including such things as apparatus work, bowling, tennis, golf, swimming, yachting, etc., were listed vertically down the left hand side of the sheet, followed by four vertical columns headed: "Now doing," "Enjoy a world, enjoy very much," "Dislike doing," and "Should be taught for its recreational value in later life." The subjects were asked to check each of the sixty-six activities under one or more of the four headings. Three hundred and thirty-five questionnaires were filled out and returned.

The returns were classified by age groups, and the five highest ranking activities in each group were listed, from which the significant facts may be culled.

In comparing the "Now Doing" and the "Enjoy" columns, dancing ranks equally high in both, indicating that all who enjoy dancing have the opportunity to dance and are dancing. Activities which rank very low in the "Now Doing" list and rank very high in the "Enjoy" column, such as boating, winter sports, equestrian sports, track and field, gymnastics, and miscellaneous outdoor activities, may be explained by the fact that the individual lacks the proper skill, time, money, or necessary facilities to engage in them. The activities which rank the highest in the "Now Doing" column, such as gardening, individual outdoor sports, game hunting, target practice, dancing, and the aquatic sports, probably rank so because they are readily available to a great number of people.

In all cases the "Recreational Value" column conforms with the "Now Doing" or "Enjoy" columns, which is logical.

"Now Doing" %	"Enjoy" %	"Dislike" %	"Recreational Value" %
20–29 Age Group (67 cases)			
65 Golf	69 Swimming	38 Marathon running	82 Swimming
56 Basketball	66 Golf	32 Dumbbells	65 Social dancing
56 Bag punching	59 Fishing	29 Wrestling	63 Volleyball
54 Swimming	57 Volleyball	27 Apparatus	56 Life saving
50 Baseball	57 Boating	26 Indian clubs	
30–39 Age Group (136 cases)			
54 Golf	62 Volleyball	32 Marathon running	81 Swimming
50 Fishing	60 Swimming	30 Wrestling	68 Tennis
45 Swimming	57 Tennis	29 Apparatus work	62 Golf
42 Gardening	57 Baseball	28 Cross country	61 Volleyball
37 Walking	54 Boating	27 Dumbbells	57 Indoor baseball
			57 Handball
40–49 Age Group (72 cases)			
58 Golf	60 Swimming	21 Field hockey	76 Swimming
45 Fishing	54 Fishing	18 Miniature golf	57 Tennis
42 Gardening	43 Bowling	17 Cross country	56 Life saving
38 Walking	43 Boating	17 Roller skating	54 Music
33 Social dancing	43 Ice skating	17 Horse racing	52 Volleyball
50–59 Age Group (30 cases)			
40 Fishing	50 Golf	20 Wrestling	60 Swimming
37 Golf	47 Swimming	13 Apparatus work	54 Social dancing
37 Swimming	33 Baseball	10 Dancing	47 Gymnastics
27 Walking		10 Social dancing	47 Music
27 Gardening		10 Dumbbells	37 Football
			37 Basketball
			37 Life saving
60–Up Age Group (23 cases)			
35 Golf	40 Swimming	13 Archery	65 Swimming
35 Walking	39 Gardening	9 Boxing	44 Golf
31 Swimming	38 Rowing	9 Billiards	44 Baseball
31 Gardening	35 Ice skating	9 Bowling	44 Gardening
26 Fishing	35 Tennis	9 Dancing	44 Gymnastics
		9 Wand exercises	44 Tennis
		9 Trap shooting	
		9 Wrestling	
All Age Group (335 cases)			
51 Golf	55 Swimming	22 Wrestling	72 Swimming
41 Fishing	49 Golf	18 Marathon running	52 Golf
37 Walking	47 Fishing	17 Apparatus work	51 Tennis
35 Gardening	45 Boating	16 Dumbbells	49 Social dancing
	42 Tennis	15 Wand exercises	48 Life saving
		15 Cross country	

CONCLUSIONS

1. The study shows that several activities not generally made a part of the physical education program, but included in its concept, are highly valued by the men answering the questionnaire. With this in mind, it is suggested that the fundamentals of these activities deserve more attention in a program designed to give the greatest value to the students.

2. Golf, tennis, fly and bait casting, roller skating, boating and canoeing, and bowling are instances of activities which probably deserve a place in the program.

3. Some of the activities, such as apparatus work, dancing, and wrestling, need either better presentation or sufficient introduction so that those who do "Enjoy" them may participate in them.

General Elements in Character

By C. H. McCloy
State University of Iowa

MUCH of the research in the field of what has been called "character" in the last two decades has tended to conclude that character education should be almost entirely specific. It has usually held that training in one type of character responses or habits has little effect upon character responses in other types of situations.

A careful analysis of the evidence supporting these claims is not entirely convincing. Some of these statements are based upon experiments in the transfer of training in fields other than character education. Many such experiments have made assumptions which seem difficult to justify in the light of the facts. It has been found, for example, that students who have had training in high school algebra have been little if any better in high school physics than those who have not had such training. This assumes that the training in high school algebra taught the student some algebra. The results of studies by Professor E. E. Lindquist of this University throw grave doubts upon the validity of this hypothesis. A very large number of such students who have been exposed to high school algebra have exhibited a high degree of natural immunity and seem to have escaped almost entirely any infection with the virus of the subject. Not having learned any algebra, it should not surprise us to learn that they do little better in high school physics than those who have not been exposed.

Other experiments more directly related to the field of character education have shown that boys who have been exposed to one type of so-called character training are not at all superior in their resistance to certain specific forms of temptation to other boys who have not been exposed to this training. On the basis of this, the statement has been made that such character training is invalid and not effective insofar as any transfer to other fields is concerned. One plausible explanation might be that the individuals not subjected to this method of character education received just as effective training in their homes and in the schools, and it is entirely possible that the method of character training used upon this experimental group was so badly conceived in form and content that little or nothing could be expected to result from it. It would seem to the writer that no real proof has been adduced to show that well conceived character training of a relatively general nature, ***when organized upon lines which would be defensible from the standpoint of the***

laws of learning, will not be effective in the sense of transferring to other and more specific situations.

If all character training to be effective must be specific, then education for character is a hopeless task and this is not in harmony with common experience. If it were true, then the experience of almost everyone of having been very much influenced by some one or more personalities would indeed be but a delusion.

In attempting to simplify this problem it occurred to us to analyze a number of character traits to see whether any general or common elements might be found which could be used as the basis for a sound educational process in character education. In this study the field was restricted to that closely related to the problems met in physical education.

Two approaches to this seemed to be feasible, and both were tried. The first was an analysis by Professor Spearman's two-factor theory. Professor Spearman's method is postulated upon the assumption that for any large number of traits there will be one common or general factor possessed in greater or less amount by all of these traits and in addition to this, each trait will be composed exclusively of a specific element. The general and specific elements together should account for all of the trait. This theory is of course limited in application to situations in which it can validly be expected that only one common element will be found. It did not seem from careful study of the traits selected that this was apt to be true. The method was tried, however, on certain subgroups of traits which seemed to have the possibility of possessing not more than one common element. These results are reported below.

The second method was that of Thurstone's factor analysis. Professor Thurstone's short or center of gravity method was selected and was used in preference to other methods available for the same type of analysis.* The Thurstone method of factor analysis enables one to analyze any given number of interrelated variables and to determine the amount of correlation each variable has with any number of elemental "factors" which are common to more than one of these variables. The process is carried out in successive steps until the diminishing returns show that no more can be expected in the line of common elements. The results from this study are reported below.

The Organization of the Study.—The junior and senior students in the School of Physical Education of the Chicago Y.M.C.A. College (now the George Williams College) were given rating sheets which had the names of forty-three traits listed thereon. The names of these traits

* See bibliography—Hotelling. Hotelling's method of analysis for common components and Kelley's multiple factor analysis involve much more work and the results give no more promise as to their accuracy and validity than those obtained from the Thurstone method. Hence, Professor Thurstone's technique was selected as being as practical as the others and much more economical of time.

are given in Table I. A short description or definition of each trait was appended and these were read to the group and explained. A method of rating in five categories was explained to the class and analyzed. Each student in the class then prepared a list of other individuals whom he felt he knew well enough to rate with accuracy. These individuals were given enough rating sheets to rate the three or four men whom each person felt most competent to rate. Each person was also asked to rate himself. These ratings were then returned to the writer for analysis. These students had lived together, for the most part, in the same dormitory for at least two years, and it is believed that the ratings are much more than usually valid.

The first step was to tabulate all ratings on each individual. It was found in general that the ratings agreed usually within one category. Most frequently all of the ratings were in entire agreement, and where they were not, usually all but one were in agreement. In cases where the ratings of others were evenly divided between two adjacent categories, the individual's own rating was used to break the tie. In general it was found that the individual's own rating agreed very closely with the majority opinion. In each case the modal rating was taken. All cases on whom ratings differed more than one category were eliminated from the study. No separate study on reliabilities was made.

A preliminary study upon a number of the traits seemed to indicate an almost normal distribution for each of the traits within the group. It was assumed, therefore, that the different categories were almost evenly spaced, and all intercorrelations were performed by the product-moment method. It is possible that this assumption introduces some degree of inaccuracy. In the light of the crudity of the ratings, however, it is doubtful if any higher accuracy would have been introduced by a greater refinement of technique.

It will be noted that a number of traits not directly related to character have been introduced, as well as two general ones, "character" and "personality." These were introduced purely because of the curiosity of the writer to see where they would stand in such an analysis. They have been left in this study and incorporated in this report because of their suggestiveness for other studies in the field of physical education.

The writer is aware that the critical reader will attack at once the device of rating *traits*. In recent years the psychological literature has more or less discredited this device and has stated that the trait as such does not correspond to anything real. The validity of this attack is acknowledged in part. We have not attempted to analyze any comprehensive list of specific situation responses, but have used trait names as a sort of magnet to draw together numerous semi-specific elements which have some general principle in common. The trait name of "cooperation," for example, includes many kinds of cooperation, many of them

quite unlike. This common element of working together with others for the accomplishment of a common end is generally recognized in all such specific situations, however, even though this method of working may be quite different in one situation than in another. Since the individual doing the rating was asked to confine the ratings to the kind of behavior exhibited in and in connection with physical education, the scope of specific responses embraced by each term was very much reduced. It is felt that this use of the trait name is in this situation justified.

Analysis by Spearman's Two-Factor Method.—The first phase of the study was conducted using Spearman's technique. As was stated above, owing to the widely varying nature of the traits rated, it seemed extremely unlikely that it would be possible to isolate any one general factor from this large number. Hence it was decided to select a number of subgroups of traits for study. Nine subgroups were studied. Each of these groups was analyzed by Spearman's technique, which gives an "r_{ug}" for each trait, which is its correlation with the element or quality which is "general" or common to all of the variables studied in the group. In the following paragraphs, the correlations will be understood to be these correlations with this general or common trait. In all of the groups studied, the tetrad differences were less than four probable errors of the difference.

I. *Qualities of Leadership*

	r_{ug}
Can Discipline Others	.65
Decisive	.56
Initiative	.65
Leadership	.82

In this case it will be found that the trait called leadership itself has the largest amount of this common element, as would be expected.

II. *Positive Active Qualities*

Aggressiveness	.67
Conviction	.71
"Fight"	.47
Initiative	.56
Perseverance	.45

In this case it will be seen that aggressiveness and conviction show the largest amount of common element.

III. *Positive Mental Attitudes*

Resourcefulness	.82
Alertness	.50
Moral Courage	.83
Self-confidence	.50
Trustworthiness	.64

Resourcefulness and moral courage stood out in this group, both, however, being traits that are difficult to rate, and, as will be seen in the later analysis, they did not stand out from the total group.

IV. *Self-Control*

Cool-headed	.80
Decisive	.40
Poise	.63
Self-control	.82
Sportsmanship	.64

Cool-headedness and self-control were the outstanding traits in this set.

V. *Traits Having to Do with Social Cooperation*

Cooperation	.77
Good Follower	.67
Respect for Law	.78
Respect for Rights of Others	.97
Trustworthiness	.76

These traits, as will be seen later, correspond to the second factor found by the Thurstone method. This is also true of the two following groups.

VI. A. *Social Action-Standards of the Gentleman*

Fairness	.43
Integrity	.84
Sportsmanship	.83
Trustworthiness	.92

This is another grouping of social traits, and here trustworthiness, integrity, and sportsmanship all stand out. Fairness, as will also be seen in the next combination, has relatively little of this particular common factor.

B.

Magnanimity	.51
Sociability	.68
Sportsmanship	.80
Trustworthiness	.82

This was a second grouping of this set of variables, substituting magnanimity for fairness and sociability for integrity. Much the same results were obtained except that sociability was inferior to integrity as a carrier of this particular quality.

VII. *Ethical Social Qualities*

A.	Fairness	.60
	Integrity	.67
	Respect for Law	.77
	Respect for the Rights of Others	1.02
B.	Fairness	.66
	Integrity	.69
	Loyalty	.75
	Respect for Law	.72
	Respect for Rights of Others	.95
C.	Good Follower	.69
	Loyalty	.74
	Magnanimity	.65
	Respect for the Rights of Others	.93
	Sportsmanship	.62

It will be seen here that "respect for the rights of others" stands out far above the rest as a correlate with the quality common to this group. In *A* its correlation, which exceeds unity, was checked and is probably due to variations in the validity of the intercorrelations. It is undoubtedly highly correlated with the common quality. This trait will be seen in the Thurstone factor analysis to also be very highly correlated with the second or social factor.

VIII. *Qualities of Efficiency*

Resourcefulness	.68
Initiative	.48
Thoroughness	.91
Trustworthiness	.80

Thoroughness is the outstanding trait in this group, with trustworthiness a close second. This is interesting in view of Webb's results† which found that "persistence of motives" was the most important element in character.

IX. *Sociability*

Leadership	.63
Magnanimity	.53
Popularity	.82
Sociability	.85

Personality and sociability itself were the important traits. It is significant that magnanimity has so little to do with this estimate.

This first phase of the study is suggestive, but is little more than that. It does indicate that a number of these variables might be selected and others rejected so far as the relative amount of common element is concerned, but it is difficult to identify the common elements and to delimit them. It is obviously desirable that a more comprehensive study be made which would attempt to determine how many such common factors there might be and what they are. This was not feasible with Spearman's method, so we resorted to the Thurstone technique in an attempt to approach the problem from this angle.

Multiple Factor Analysis.—In the use of any method of factor analysis the analysis is facilitated when not more than three common factors are found to be present. This enables the factors isolated to be plotted in three dimensions, usually in three orthogonal planes. Fortunately, this was found to be the case in this study, as the fourth and fifth factors proved to be specific. When the common factors are plotted in three dimensions, the original orthogonal planes are usually not the planes that correspond to the "real" origins or axes. Some method of rotation must be used. The writer has demonstrated and will publish elsewhere evidence

† Edward Webb, "Character and Intelligence," *British Jr. of Psych. Monograph Supplement*, No. 1, 1915.

to support the statement that in variables such as those used in this study, mathematically fitted planes usually do not represent the facts as well as what might be termed "logically fitted planes." In this study these common factors, or what Professor Thurstone terms factor loadings, were plotted in three dimensions on a globe, as though extended in each case to the surface of the globe. A qualitative study was made of these factors and planes were fitted logically. These logically fitted planes were then further fitted mathematically in order to obtain the revised factor loadings or zero-order correlations of each trait with each of the three common factors. These are shown in Table I.

Further study of these factors enabled us to identify them beyond any reasonable doubt. The first factor was called "positive self feeling," the opposite pole being "negative self feeling." This is illustrated in the one extreme by aggressiveness and in the other by modesty. The second common element was called "social qualities" as contrasted with "anti-social qualities." Social in this sense is to be distinguished from sociable and may be taken to mean those qualities which are beneficial to society or which are the qualities of a good citizen. There is a large group of such qualities led by such traits as trustworthiness, sportsmanship, respect for the rights of others, and thoroughness. There were no strongly anti-social traits, the nearest approach being egotism. The third common element is a little more difficult to name. It seems to be "individual qualities" as contrasted with the type of trait that tends to merge with the group. This is the sort of thing which, in the terms of one of our popular magazines, causes one to "stand out from the crowd." It is the opposite of the sort of thing which causes the person to merge with other gregarious individuals and lose his individual identity, which may, of course, in many cases be a desirable thing.

The forty-three traits studied correlate in varying degrees with each of these three common elements. In none of them is absolutely everything accounted for by these three factors. It is highly probable, however, that the differences between the total correlation of these three elements and unity is accounted for more by inaccuracy and errors of rating than it is by certain specific elements. Until such a study is made on much more valid ratings and measurements, the relative amounts of specifics and errors must remain in doubt. Since this study is concerned only with the common elements, and since the specific elements may be reasonably well deduced from the definition of the trait, these specifics need not concern us further. Two of these traits studied were of a general nature, "character" and "personality." It will be seen that these traits correlate highly with the second or "social" factor.

Three others, "athletic ability," "health," and "vitality," were included to satisfy the curiosity of the writer. Athletic ability correlated more highly with the third of "individual qualities" factor than did any

TABLE I

The correlations given under columns I, II, and III represent correlations with the common factors. These factors are identified by name at the head of the column. The column labeled "hypotenuse" indicates the relative distance away from the origin at which the trait is located when the factors are plotted in three dimensions, and enables the reader to determine how much of the trait is represented by the common elements and how much by specific elements. That accounted for by the general elements may be taken as the square of this hypotenuse, while the amount accounted for by specific elements and by errors of rating may be taken as $1 - \text{hypotenuse}^2$. It should be emphasized, however, that this error of rating is probably fairly large. Hence it is probable that were the ratings more accurate, the amount of the common elements would be larger and the amount of the specific element relatively smaller. In view of the probable large error of rating, no valid attempt may be made to estimate the amount of specific elements.

	Positive I	Social II	Group vs. Indiv. III	Hyp.
1. Resourcefulness	.2233	.7439	.2502	.8160
2. Aggressiveness	.7822	.2542	.3030	.8766
3. Alertness	.1819	.4869	.4009	.6564
4. Athletic ability	—.0318	.3627	.7381	.8229
5. Character	.0959	.7592	—.2921	.8161
6. Cooperation	—.0668	.6548	—.3825	.7612
7. Can discipline others	.6193	.4628	—.1167	.7819
8. Conviction	.4301	.4077	.1215	.6048
9. Cool-headed	.0837	.6372	.2836	.7025
10. Decisive	.3038	.4213	.0769	.5252
11. Egotistical	.2702	—.0595	.1969	.3396
12. Enthusiasm	.3985	.3852	—.3328	.6465
13. Energy	.4327	.2327	.0203	.4917
14. Fairness	—.0173	.5570	—.3030	.6344
15. Fight	.1026	.5157	—.0122	.5259
16. Good appearance	.0914	.4658	.3465	.5876
17. Good follower	—.1014	.6018	.0524	.7336
18. Hard worker	—.0026	.6867	.0282	.6873
19. Health	—.2650	.6215	.1762	.6991
20. Initiative	.6192	.3648	.1111	.7273
21. Integrity	—.0331	.7492	—.3545	.8295
22. Leadership	.3550	.6933	—.0806	.7830
23. Loyalty	—.1817	.7629	—.1632	.8011
24. Magnanimity	.1082	.6205	—.0660	.6332
25. Modesty	—.4091	.3666	—.0303	.5501
26. Moral courage	—.1015	.7327	.1487	.7545
27. Perseverance	—.0487	.6998	.0137	.7016
28. Personality	.0007	.7772	.1197	.7864
29. Physical courage	—.1903	.7540	.0000	.7777
30. Poise	.3057	.5161	.4213	.7329
31. Popularity	.2417	.5984	.5386	.7256
32. Adaptive	.5690	.3317	.1241	.6702
33. Respect for law	.1352	.5780	—.2874	.7229
34. Respect for the rights of others	—.0108	.7858	—.3551	.8624
35. Self-confidence	.6257	.2990	.0995	.7006
36. Self-control	.1459	.5677	.2426	.6336
37. Sociability	.0898	.7488	.2969	.8106
38. Self-sacrifice	.2568	.5900	—.1325	.6570
39. Self-denial	.1247	.6037	—.3540	.7108
40. Sportsmanship	—.0514	.8134	.0806	.8190
41. Thoroughness	.2458	.7760	.0000	.8140
42. Trustworthiness	—.0039	.8267	—.1711	.8443
43. Vitality	—.0217	.7333	.1885	.7575

other trait. Owing to the fact that the subjects were physical education majors, however, this fact may be discounted considerably. "Health" and "vitality," however, correlated surprisingly highly with the "social" factor, and the writer feels that this fact should at least be given thoughtful consideration in character education and mental hygiene programs.

The next step in this analysis was to select the traits which correlated most highly with each of these three factors and their opposites, and to attempt to compute multiple correlations of these traits with the general factor. This was done in two ways. After the first selection of traits correlating highest with each variable was made, the multiple correlation with the general element was computed by Spearman's method. Since it is held by Professor Thurstone that each of these factor loadings is comparable to a zero-order correlation with a criterion, it was further assumed that the ordinary multiple correlation formula might be used and multiple correlations were performed according to the usual techniques, and they corresponded very closely indeed with the Spearman results. Both of these results are given in Tables II to IV. It will be noted that in these lists a number are omitted that were found to be high in "*g*" in one or another of the groups analyzed by the Spearman technique. This is because of the fact that while they were rich in some common element (as will be seen by referring to Table I), others possessed more of it, and therefore were given preference. A number of such lists of traits might be selected, each quite valid and valuable as a criterion of the general factor involved.

The next step was to reduce the number of traits rated as much as possible without reducing unduly the multiple correlations. These results are also seen in Tables II to IV.

CONCLUSIONS

From these results it would seem to be implied that a number of character qualities may be reduced to three important common or fundamental elements which are overlaid by a number of specific elements. It would further seem that these three common elements may be very accurately measured by a number of properly combined ratings, assuming, of course, that the individuals are well known to the raters and that enough raters are used to validate the results to within a reasonable degree of accuracy. I would therefore like to propose the basis of a tentative procedure for character education as related to the field of physical education.

1. In most situations these general factors are obscured or camouflaged by a mass of specific detail. It should be the endeavor of the educator to bring these common factors to light and, as it were, strip off their camouflage of specifics, and by the use of what Thorndike has termed the principal of partial activity focused upon these pre-potent

TABLE II

MULTIPLE CORRELATIONS OF COMBINATIONS OF TRAITS CORRELATING HIGHEST WITH THE FACTOR OF "POSITIVE SELF-FEELING"

"*Ro.123.....n*" may be read to mean "the multiple correlation between the best combination of variables 1 to *n* with the criterion." "R_{pg}" may be read to mean the "multiple correlation (of the same variables) with the criterion, as computed by the Spearman formula for a correlation of '*g*' with the pool."

Variables:
1. Aggressiveness
2. Initiative
3. Decisive
4. Self-confidence
5. Can discipline others

Ro.12345	.843	R_{pg}	.893
Ro.123	.841	R_{pg}	.860
Ro.12	.832	R_{pg}	.831

TABLE III

MULTIPLE CORRELATIONS OF COMBINATIONS OF TRAITS CORRELATING HIGHEST WITH THE "SOCIAL" FACTOR

Variables:
1. Thoroughness
2. Sportsmanship
3. Respect for the rights of others
4. Loyalty
5. Perseverance
6. Resourcefulness
7. Trustworthiness
8. Physical courage

Ro.12345678	.974	R_{pg}	.949
Ro.1234567	.973	R_{pg}	.945
Ro.123456	.973	R_{pg}	.944
Ro.12345	.969	R_{pg}	.939
Ro.1234	.957	R_{pg}	.931
Ro 123	.936	R_{pg}	.915
Ro.12	.874	R_{pg}	.881

TABLE IV

MULTIPLE CORRELATIONS OF COMBINATIONS OF TRAITS CORRELATING HIGHEST WITH THE FACTOR OF "INDIVIDUAL QUALITIES"

Variables:
1. Poise
2. Popularity
3. Alertness

Ro.123	.620	R_{pg}	.670
Ro.12	.609	R_{pg}	.670
Ro.23	.564	R_{pg}	.612

MULTIPLE CORRELATIONS OF COMBINATIONS OF TRAITS WITH THE FACTOR OF "TENDS TO MERGE WITH THE GROUP"

Variables: 1. Cooperation
2. Integrity
3. Respect for the rights of others

$R_{o.123}$ .419 R_{pg} .561

elements, sensitize the individual to certain general factors and cause him to readily recognize these fundamentals in all situations.

2. The process involved in the transfer of training to be expected should not be merely to hope for common elements to thrust themselves before the attention of the pupil, nor simply to hope that he will generalize upon such common elements as come to his attention, but a positive endeavor should be made to cause the individual to intellectualize these principles in such a way to project them into areas of behavior as yet unmet in experience, in order that he may have general rules of behavior based upon intelligently analyzed concrete experiences which have involved these three important fundamental factors of character.§

3. It should then be the privilege of the instructor to take advantage of various situations as they arise in his instructional periods to constantly point out these common elements and strengthen and guide this intellectualizing process until the application becomes semi-automatic.

4. Finally, it is suggested that the process of rating behavior in its educational aspects, particularly from the aspect of behavior qualities which the instructor desires to inculcate and strengthen, may be much simplified by refraining from rating a great mass of details, and rating instead development in these fundamental qualities.

This paper makes no attempt to develop these proposals or theories into a system of character education. It is meant merely to be a report of a research, together with suggestions which would seem to spring from the results of the study.

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§ This process might be illustrated in a homely way by an experience which is common to many automobile drivers. Many people have told the writer that they have anticipated their behavior in certain as yet not experienced emergencies. These responses were rehearsed in imagination with the result that when the emergency did present itself the individual had really experienced the response in imagination and hence responded according to schedule, with the desired effect. The same principle may be extended to other aspects of behavior if in discussions of principle, when these principles are grounded on fundamental factors, the individual is led to tie up present concrete situations with types of behavior situations as yet unmet, but which are likely to be met in later life.

The Prediction of Heart Size by Anthropometric Measurements in Adult Males

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INTRODUCTION

NUMEROUS investigations have been made in the past in an attempt to set up a formula for determining heart size by anthropometric measurements. Despite the doubt that may still exist in the minds of many as to the reliability of certain investigations, the results pursue a general trend which, by preponderance of evidence, may be interpreted as pointing toward a rather definite conclusion.

In this study an attempt has been made to determine a formula for heart size, as measured by the silhouette on the X-ray, by a greater number of anthropometric measurements than height, weight, or body area.

REVIEW OF LITERATURE

Historically, the size of the heart has been an object of much interest, and much has been written about it. We first find the heart compared to the size of a closed fist (Laennec, 1819). Later investigators compared its width to one-half the width of the chest. With the more extensive use of X-rays attempts have been made to study the size of the heart more objectively.

PROCEDURE

Fifty male subjects, between the ages of nineteen and thirty-seven, were used.

The following procedure was used:

I. An X-ray of the thorax of each subject was taken. The subject lay in a prone position on the film, which was at a distance of seventy-two inches from the tube. This distance was considered desirable because the photograph will approximate the actual size. Each subject was asked to take a deep breath and hold it during the exposure which was for one second. The object of holding the deep breath was to restrict movement as much as possible and keep the film from unnecessary blurring. The exposure for one second gave a shadow of the heart in diastole, which removed the possible error of having the exposures at different stages of the heart cycle.

II. A number of anthropometric measurements were taken on each subject. The measurements were made according to the "International Agreement for the Unification of Anthropometric Measurements" (Geneva, 1912). For any new measurements or deviations from this agreement the technic is explained with the measurement. The following measurements were made:

1. Age—to the nearest birthday.
2. Height—in centimeters.
3. Weight—in pounds. This was changed to kilograms.
4. Suprasternale—this was taken with the subject sitting on a stool with the hips and shoulders against the wall. The subject "sat tall." Measurement was from the top of the stool to the top of the sternum. Care was taken to see that the anthropometer was held perpendicular to the stool, which had a flat surface.
5. Xiphoid—sitting height to the xiphoid. Same method as for suprasternale (4) except that the measurement was from the top of the stool to the xiphoid at the base of the sternum.
6. Sitting height to umbilicus. Same as for suprasternale (4), measured from the top of stool to umbilicus.
7. Chest girth—taken at level of xiphoid.
8. Chest breadth—taken at level of xiphoid.
9. Chest depth—taken at level of xiphoid.
10. Shoulder breadth—biacromial width.
11. Hip width—bi-cristal width.
12. Elbow width—elbow held at right angle. The calipers were brought up from beneath, placed over the epicondyles so as to approximately bisect the right angle. Pressure was used before the reading was taken.
13. Knee width—same method as for elbow width.
14. Hand length—projection of dactylion upon stylion.
15. Hand breadth—greatest width of palm.
16. Finger length—from proximal end of the first phalanx to the tip of the index finger.
17. Palm length—from proximal phalangeal crease to the stylion.
18. Length of head—from glabella to episthocranion.
19. Breadth of head—from euryon to euryon.
20. Face diameter (bizygomatic)—from zygion to zygion.
21. Bigonial diameter—from gonion to gonion.
22. Face height—from nasion to menthon.
23. Upper face height—from nasion to prosthion.
24. Nasal height—from nasion to subnasale.
25. Nasal breadth—from alare to alare.
26. Face index.
27. Upper face index.
28. Nasal index.
29. Hand index.
30. Chest index.
31. Suprasternale-Xiphoid.
32. Heart area.

III. The areas of the hearts as shown in the X-ray were measured with a planimeter. This is measurement 32.

IV. Correlations were set up between the heart area (32) and the other measurements, with the exception of age.

ANALYSIS OF DATA

Measurements showing a very low zero-order correlation with heart area were arbitrarily dropped. Doubtful measurements were analyzed by partial correlations to eliminate them or justify their being retained. These two steps eliminated all except 2, 3, 8, 11, 13, 20, 22, 25, the intercorrelation between which are as follows:

Identification		2	3	8	11	13	20	22	25
Weight	2		.4309	.7520	.7143	.7503	.5658	.2205	.2668
Height	3	.4309		.2231	.6518	.4293	.3164	.5852	.3153
Chest breadth	8	.7520	.2231		.5204	.5485	.5662	.2750	.4621
Hip breadth	11	.7143	.6518	.5204		.6728	.4748	.3996	.3543
Knee breadth	13	.7503	.4293	.5485	.6728		.5173	.3525	.0638
Bizygomatic	20	.6658	.3164	.5662	.4748	.5173		.3735	.4558
Face length	22	.2206	.5953	.2750	.2996	.3625	.3757		.3148
Nose breadth	25	.2668	.3153	.4621	.3543	.0638	.4558	.3148	
Cardiac area	32	.5045	.4185	.3988	.5645	.4145	.4875	.4544	.4715

Second order partial correlations were set up between the criterion variable and each of these variables with the two measurements giving the highest intercorrelations with the variable held constant, as for example: $r\ (32)\ (13).(2)\ (11) = -.0406$, which justified the dropping of 13, knee width; similarly 3, height, was eliminated by hip width and face length.

A multiple regression of the six remaining measurements was worked out, giving:

Formula I

(units in cm. and kg.)

Heart area = 8.907 (face length) + .395 (weight) + 11.116 (nose width) + 1.907 (hip width) — 95.69.

A similar regression equation was worked out for two variables, giving:

Formula II

Heart area = 13.375 (nose width) + 4.067 (hip width) — 26.002 in which the multiple correlation was .6348.

The predicted heart area by Formula I correlated .6990 with the measured heart area. The predicted heart area by Formula II correlated .6575 with the measured heart area.

A multiple regression equation was also computed from height and weight giving:

Formula III

Heart area = .6882 (height) + .6286 (weight) — 20.16.

The multiple correlation was .5595 which was approximately the same as that secured by Hodges and Eyster (.565), though the formula differed somewhat.

The correlation between surface area, as computed by Du Bois formula, and heart area was also computed, resulting in a correlation of .5416.

The correlation between Formula I and Formula II is .8259.

It would seem that in view of the significantly high correlations given by Formula I, that it should be preferred.

No logical explanation of the significance of nose width and of face length is attempted. The important thing is that they do give more important information than do the other variables without them.

The multiple correlation of the best combination of weight and hips is but .5840, while that of nose width and face length alone is .5310, almost as large as that obtained from height and weight.

CONCLUSION

Twenty-five anthropometric measurements and six indices were used in an attempt to predict with as great a degree of accuracy as possible the area of the heart shadow on a posterior-anterior X-ray. From these measurements three multiple regression formulae have been developed and compared with formulae proposed by other students of this question. These multiple correlations were somewhat higher than those suggested by other workers, apparently predicting heart area about 54 per cent more accurately than the best of those, in terms of the coefficient of alienation.

The standard error of estimate of heart prediction from these data is 10.57 square centimeters. Studying the cases upon whom this research was made, 8 cases are more than 1, no case more than 2 standard errors of estimate above the average regression values; while 6 cases are 1, 1 case 2, and 1 case 4 or more standard errors of estimate below the regression values.

In this study no attempt was made to check upon the hearts medically. The distributions of the shadows of the heart were more widely spread on the small size than on the large size. This would suggest the possibility that many hearts may be *too small* for athletic competition, and that a more careful check should be made on the hearts of prospective distance runners or those who wish to take part in strenuous endurance contests. It is not improbable that, with the possible exceptions of a very small number of cases, the hearts used in this study fell within the normal range of variation.

This study makes no attempt to interpret the findings clinically. Suffice it to say that the regression equations present the size of the heart shadow in terms of the averages for that size and build; and that the deviations from this average should at least be investigated carefully. This is especially true of those more than one standard deviation of estimate from the regression norm.

Factor Analysis Methods in the Measurement of Physical Abilities

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FACTOR ANALYSIS METHODS

EDUCATORS have always concerned themselves with the measurement of abilities, and educational research has to a large extent been directed toward the development of more refined and more precise measurement techniques. While educational testing has greatly improved in accuracy since its first crude beginnings, those interpreting the test results are still somewhat hampered by the difficulty experienced in identifying and isolating the factors which are tested, and in determining the extent to which each factor is measured by any given test, or battery of tests. However, the last few years have witnessed the development of factor analysis techniques which are proving very useful in partially overcoming this difficulty. These techniques are being used quite extensively in the field of psychological testing, and the results which have been reported by research workers in this field point to the possibility that the same methods may be applied to advantage by those who are interested in the accurate measurement of physical abilities.

The first approach to the problem of factor analysis was made by Professor Charles Spearman in his so-called "*g-s*" method. His basic theorem may be stated as follows:

"Four variables may be considered as due to one factor (g) plus four uncorrelated specific factors (s) when $r_{12}r_{34} = r_{14}r_{23}$,"[1]* where r is any correlation, and the subscripts represent the abilities correlated. This formula has been termed the "tetrad equation." In practical use, there are three equations to be satisfied. These are

$$r_{12}r_{34} - r_{13}r_{24} = 0$$
$$r_{12}r_{34} - r_{14}r_{23} = 0$$
$$r_{13}r_{24} - r_{14}r_{23} = 0$$

In each case, the left side of the equation is known as the "tetrad difference."

Spearman[2] has presented several formulae by which it is possible to determine the extent of the correlation between any variable and "*g*,"

* Numbers refer to bibliography at the end of the article.

and by which the relative amount of "*g*" may be computed for each individual.

The "*g-s*" method of Spearman is limited in its applicability since it is adequate for only one type of situation, namely, that where the variables analyzed possess one and only one common component, while every other component is specific to each separate variable, with no overlapping. Statistical workers have devised various methods for removing the limitations imposed by Spearman's method. At present there are two techniques quite widely used which accomplish essentially the same thing. The first of these is Thurstone's method of "factor analysis," and the second is Hotelling's method of "analysis of a complex of statistical variables into principal components." Since Thurstone's method is somewhat simpler than that of Hotelling, it is the one used and discussed in the present study.

By means of Thurstone's method of factor analysis, any battery of tests may be analyzed for its common factors, and the factor loadings for each test may be obtained. A "common factor" is here used to mean any element which is common to two or more variables.

Thurstone, in presenting his method, finds it convenient to think of each variable analyzed as a point in space of as many dimensions as there are common factors. For example, when there are three common factors, each variable is represented as a point on the surface of a sphere. If 2 abilities tend to coexist, then they are represented as 2 points which are close together on the surface of the ball. If they are negatively correlated to the extent of —1.00, they will be represented as points which are diametrically opposite. If they are uncorrelated, they will be separated by 90 degrees.

When the original factor loadings are obtained, these do not necessarily represent the correct correlation coefficients between each variable and each common factor. In order to get the true factor loadings, it is necessary to examine the original loadings and the way in which the points cluster on the surface of the sphere (if there are three common factors). Then, following a logical analysis, the coordinate axes must be rotated and the true factor loadings graphically obtained. A more detailed description of methods of factor analysis is given elsewhere.[3, 4, 5]

It must be understood that Thurstone's method isolates the common factors present, and indicates the correlation of each factor with each variable, but it does not identify any of the factors. This must be done by the individual who interprets the factor loadings.

PROBLEM

The problem in the present study is to test out the relative applicability of the factor analysis methods of Spearman and of Thurstone, by applying them to a battery of athletic events and strength tests.

DATA

The data used in this study were gathered at the Gorton High School, Yonkers, New York, and were secured by the courtesy of Dr. H. Leigh MacCurdy.

Tests were taken on 294 boys, using the following variables:

Age (12 to 19)	Leg lift
Height	Back lift
Weight	Right grip
Dash—yards run in 10 seconds	Left grip
Running high jump	Chins†
Shot put	Dips†
Running broad jump	

PROCEDURE

In the first part of the study, two batteries of tests were considered: one made up of the four track and field events, and the other made up of four strength tests, including leg lift, back lift, left grip + right grip, and chins + dips. In the following procedure, each battery was considered separately.

Intercorrelations of the variables in each battery were made, and the applicability of Spearman's method was tested out by the use of the tetrad equations. The tetrad differences were all approximately zero, and were less than their probable errors, so this criterion was satisfied. Next, the zero-order correlation of each test with "*g*" was determined, as well as the partial correlation of each test with "*g*," when weight was held constant. Finally, Holzinger's formula was used to find the best weighted pool of tests for "*g*."

In the second part of the study, eleven variables were used in a single battery, including weight, dash, running high jump, shot put, running broad jump, leg lift, back lift, grips, chinning strength, dipping strength, and the Classification Index. These were all intercorrelated, and the table of intercorrelations was analyzed by Thurstone's method of factor analysis. The variables were plotted as points on the surface of a sphere, and the final factor loadings were computed after the axes were rotated.

Two hundred and seventy-two cases out of the original 294 were included in the second part of the study.

RESULTS

Part I. Two-Factor Analysis

A. *Athletic Events.*—The intercorrelations for the athletic events are shown in Table I. Correlations between each of these events and "*g*" are as follows:

$r_{1g} = .8485$ $\quad r_{3g} = .7706$

$r_{2g} = .8304$ $\quad r_{4g} = .8946$

† McCloy's formula was used in computing arm strengths.

where 1 = dash, 2 = running high jump, 3 = shot put, and 4 = running broad jump. When weight was partialled out, these coefficients became, for each of the four events, respectively, .8185, .8170, .7421, and .9092.

TABLE I

TABLE OF INTERCORRELATIONS FOR ATHLETIC EVENTS

$N = 294$

	1	2	3	
2	.6993			1 = Dash
3	.6538	.6421		2 = High Jump
4	.7599	.7443	.6857	3 = Shot Put
				4 = Broad Jump

These results show that the running broad jump has the highest correlation with "*g*," and the shot put the lowest. However, all of the coefficients are sufficiently high to warrant the conclusion that there is some one common factor here which is significantly related to performance in each of these events. This result seems rather surprising, inasmuch as athletic ability has, by logical analysis, been attributed to the combined effect of a number of common factors. The only explanation of this seeming paradox appears to lie in the possibility that the "*g*" here is athletic *power*, which, we know, is dependent upon force (strength) and velocity.

The best pool of tests to measure "*g*" for track and field events, when age, height, and weight are not considered, is 3.03 dash + 2.67 high jump + 1.90 shot put + 4.48 broad jump, where performance in each event is expressed in terms of a sigma score.

B. *Strength Tests.*—The intercorrelations for the strength tests are shown in Table II. Correlations between the different variables and "*g*" for this battery are as follows:

$r_{ag} = .7125$ $\qquad$ $r_{cg} = .8540$

$r_{bg} = .8429$ $\qquad$ $r_{dg} = .8672$

TABLE II

TABLE OF INTERCORRELATIONS FOR STRENGTH TESTS

$N = 294$

	a	*b*	*c*	
b	.6144			*a* = Leg lift
c	.6022	.7064		*b* = Back lift
d	.6031	.7299	.7592	*c* = Shot put
				d = Broad jump

where *a* = leg lift, *b* = back lift, *c* = grips, and *d* = chins + dips. When weight was held constant, these coefficients became, respectively, .6717, .7436, .7848, and .5010.

Although, in a well developed person, the muscles constitute approximately 40 per cent of the weight of the body, weight is apparently not

synonymous with "*g*." Perhaps the best way to label this common factor for strength tests would be simply to call it "general strength."

The best pool of tests to measure "*g*" for the strength tests, when age, height, and weight are not considered, is 1.44 leg lift + 2.95 back lift + 3.15 grips + 3.40 chins + dips, strength being measured in terms of sigma scores.

C. *Relation between Pool of Strength Tests and Pool of Athletic Tests.*—The correlation between the pool of strength tests and the pool of track and field events is .6364. When age, height, and weight are partialled out, this is lowered to .5383. Since athletic power is equal to force × velocity, and since we have suggested that "*g*" for athletic events may be "power," a relation between the two common factors would be expected.

Part II. Multiple-Factor Analysis

Table III shows the zero-order correlations which were analyzed by Thurstone's method.

The results of the factor analysis indicated the presence of *three* common factors in the battery of tests. The factor loadings for each variable are shown in Table IV. These are the values which were ob-

TABLE III

Table of Intercorrelations of Tests Used for Thurstone Analysis

$N = 272$

	1	2	3	4	5	6	7	8	9	10
1. Weight										
2. Dash	.4333									
3. High jump	.3560	.6366								
4. Shot put	.6590	.6444	.6514							
5. Broad jump	.4291	.7453	.7080	.6802						
6. Leg lift	.5917	.3675	.3476	.5331	.4110					
7. Back lift	.6061	.4318	.3272	.5278	.4067	.6752				
8. Grips	.7345	.4875	.3918	.6087	.4722	.6164	.7022			
9. Chins	.8617	.6123	.5206	.7591	.5939	.6568	.6647	.7663		
10. Dips	.8281	.5861	.4584	.7102	.5730	.6565	.6700	.7626	.9020	
11. C.I.	.8828	.5089	.4432	.6612	.5096	.5451	.6183	.7480	.8107	.7675

TABLE IV

Multiple Factor Analysis of Physical Abilities; Correlations of Variables with Common Factors

Test	Factor I	Factor II	Factor III
Weight	*.5524*	.0000	*.7745*
Dash	*.5475*	*.6298*	—.0219
High jump	*.4307*	*.6892*	.0319
Shot put	*.6629*	*.4929*	.2534
Broad jump	*.5311*	*.6922*	—.0125
Leg lift	*.7708*	.0000	.0000
Back lift	*.8412*	—.0294	—.0672
Grips	*.8529*	.0223	.1504
Chins	*.8430*	.2104	*.3782*
Dips	*.8560*	.1509	*.3078*
C.I.	*.7782*	.1232	*.4367*

tained after rotating the axes. Figure I shows the manner in which the variables clustered when they were plotted as points on the surface of a sphere.

In Table IV, those factor loadings which are higher than .30 are in italics. These are the only ones which are high enough to warrant serious consideration.

An examination of the correlations between the variables and each factor shows that Factor I correlates significantly with every variable considered. Its highest correlations are with the strength tests, and with the Classification Index. Referring back to the Spearman analysis, it is apparent that the correlations between Factor I and the strength tests are very close to the correlations found between these tests and "*g*." Further, the shot put is more heavily weighted with this factor than are any of the other athletic events, and the average of the correlations between the athletic events and Factor I is .5431, which is a value not far from the correlation found between the "*g*" for athletic events and that for strength tests. It seems fairly safe, then, to call Factor I *strength*.

Factor II correlates positively with each of the four athletic events, having the highest coefficient for the running broad jump and the lowest for the shot put. These coefficients are lower than those found when the athletic events were correlated with "*g*," so apparently Factor II is not

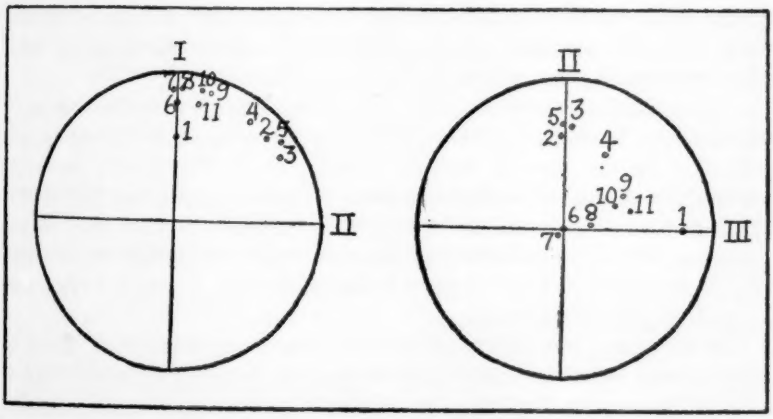

FIGURE 1.—Graphical Representation of Factor Analysis.

The variables here are plotted so that $D_h/R = L_v$, and $D_v/R = L_h$, where D_h and D_v are distances from the horizontal and vertical axes, respectively, R is the radius of the circle, and L_v and L_h are loadings for factors represented by vertical and horizontal axes, respectively. These loadings are found in Table IV. In this figure, 1 = weight, 2 = dash, 3 = high jump, 4 = shot put, 5 = broad jump, 6 = leg lift, 7 = back lift, 8 = grips, 9 = chins, 10 = dips, 11 = classification index, I = strength factor, II = velocity factor, and III = weight factor.

identical with that factor which was called "*g*" for athletic events. Once more we return to our force × velocity formula. We know that speed or velocity plays an important part in athletic ability. We know also that velocity does not enter into weight at all, and probably is not significantly related to strength. This factor, then, we may call *velocity*.

The third factor is not as easily identified as Factors I and II. It is more highly correlated with weight than with any other variable, but is related also to the Classification Index, chinning strength, and dipping strength. At first glance, we would appear to be justified in calling this factor "weight," since we know that weight enters into the Classification Index, and that the methods of testing arm strength make weight an important factor there. However, if this factor is "weight," in the most inclusive sense of the term, then the correlation between Factor III and the first variable should be 1.00. The actual correlation coefficient is somewhat lower, making this interpretation doubtful. But if we consider "weight" as that part of the total weight which does not contribute to strength, then the figures would appear to fit the interpretation more closely. We may, then, *tentatively suggest* that Factor III is "dead weight."

DISCUSSION OF RESULTS

In the analysis of the athletic events by Spearman's method, it was suggested that "*g*" in this case might be athletic *power*. The Thurstone analysis confirms this interpretation, since the square root of the sum of the squares of the factor loadings for the first tv) factors gives, for each of the four athletic events, a value which is a. ost identical with that representing the correlation of the variable with '*g*."

In comparing the results of the Spearman analysis with those secured by Thurstone's method, it is evident that Spearman's technique is not adequate in the case of athletic events, since Thurstone's methods showed "*g*" to be not a single common factor, but an effect due to the combined action of speed and strength. Spearman's method gives us no clues concerning the relative part played by the two factors, in accounting for the amount of "*g*" in each event, so that, as a practical measure, it is of very little use to us.

In the case of strength tests, however, the Spearman analysis checked very closely with the Spearman results. In this case, the two-factor method was quite adequate, because only one common factor was involved. Weight, apart from strength, was probably a specific factor for chins plus dips.

The results of this study seem to show, rather strikingly, that the Spearman "*g-s*" method is useful when it is desired to measure a general element running through a series of relatively homogeneous tests which have only one factor in common. Strength tests have been given as an illustration in point. However, when more complex abilities are analyzed,

such as, for example, those accounting for performance in track and field events, it is necessary to have a method by which the complex abilities may be reduced to simpler elements. This is beyond the scope of Spearman's method, but is quite possible by the use of Thurstone's technique.

SUMMARY

By a two-factor analysis of four track and field events, and four strength tests, the track and field events were found to have a factor in common, and the strength tests were found to have a factor in common. The common factors for the 2 batteries of tests were found to be correlated to the extent of .6364.

By a multiple factor analysis of eleven variables (including weight, Classification Index, four track and field events, and four strength tests), three group factors were found. The first of these was found to be significantly related to all eleven variables; the second was related to ability in track and field events; the third was related to weight, arm strengths, and the Classification Index. The first of these factors was identified as strength, and the second as velocity. The third factor was tentatively identified as that part of weight which does not contribute to strength.

In comparing the results obtained by means of the two methods of factor analysis, Spearman's method was found valid for cases where the variables are homogeneous and the tests involve simple abilities with only one factor in common. However for complex skills, involving more than one common element, Spearman's method gives results which are quite unsatisfactory. Thurstone's method, on the other hand, successfully locates the separate factors involved in each ability, and indicates the degree to which the complex performance is accounted for by each factor.

In spite of its limitations, factor analysis provides an approach which promises to be most fruitful in solving problems which for some time have baffled research workers in physical education.

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A Study of the Relationships between the "General Factor" in Events Primarily Depending upon Strength, and the "General Factor" in Four Broad Jumps, Using Spearman's Method of Analysis for "G"

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FOREWORD

As GENERAL intelligence tests have been devised to measure general mental ability, so general athletic ability tests are being proposed in the field of physical education. What do these tests measure? When several tests are pooled together, does each of them measure ability proportionately? Could some parts be eliminated and others substituted to improve the test? Could we cut the number of tests down to a minimum and still measure general athletic ability* accurately? Questions such as these actuated this study.

Spearman has devised a method whereby he determines the amount of *general ability* common to a group of tests as opposed to the specific ability measured by each test. This "general something" he calls the "*g*" factor.

This study proposed to apply the Spearman technique of measuring "*g*" to certain tests of physical abilities.

THE DATA

The Detroit High School Decathlon tests were used. The group that was selected were all fifteen-year-old boys who had qualified to take part in the annual Belle Isle track meet and who represented the best 3 per cent of all boys in school of that age. The measurements of four hundred boys were taken from the individual cards that are kept for each boy. The height and weight of each boy was also taken. The events were all supervised by qualified and experienced people, insuring fairly accurate measurement. The boys were in competition as individuals, thus practi-

* The term "general athletic ability" should be interpreted to mean the underlying abilities that are fundamental to all athletic performance in any defined field of athletics, and that are common to all such athletics.

cally assuring maximum performance. The scoring method used for the sit up, chin, and dip was as follows: weight + 2 (number of times he does the exercise).†

Eight of the ten events were taken and divided into two groups. The one group is made up of four tests that obviously measure mainly strength, and will be called the "Strength Tests." The second group obviously measured jumping ability and will be called the "Broad Jump Tests."

Strength Tests	*Broad-Jump Tests*
1. Chin	1. Standing Broad Jump
2. Dip	2. Running Broad Jump
3. Sit up	3. Standing Hop, Step, and Jump
4. Shot put	4. Running Hop, Step, and Jump

Ultimately it will be desirable to take a complete group of athletic tests and by the Spearman method try all the combinations to get a group of tests that correlate almost perfectly with "*g*." That group will then in itself measure "*g*," that certain something that the athlete has, but in this case it is confined to the "jumps" and the "strengths."

THE SPEARMAN TECHNIQUE

The writer has attempted to follow the Spearman technique as illustrated by Karl J. Holzinger in his *Statistical Résumé of the Spearman Two-Factor Theory*.[1]

1. *Correlations for Each Group.*—Correlations of the different events in each group were made as in Table I.

TABLE I

CORRELATIONS OF EVENTS

Strengths						Jumps					
Event	1	2	3	4	5	Event	1	2	3	4	5
1. Chin						1. St. Br.					
2. Dip	.795					2. Run Br.	.494				
3. Sit up	.620	.567				3. St.H-St	.486	.466			
4. Shot	.529	.525	.360			4. Runn'g					
5. Height	.542	.766	.418	.367		H-Step	.456	.529	.606		
6. Weight	.918	.829	.580	.565	.582	5. Height	.284	.251	.311	.244	
						6. Weight	.340	.291	.263	.286	.582

According to the two-factor theory of Professor Spearman, mental abilities may be divided into two factors, one being denoted by "*g*," the common factor, and the other by "*s*," the specific factor.

† Adapted from formula given by C. H. McCloy, "A New Method for Scoring Chinning and Dipping," *Research Quarterly*, II:4 (Dec., 1931), 132-143.

[1] Karl J. Holzinger, *Statistical Résumé of the Spearman Two-Factor Theory*, Chicago: University of Chicago Press, 1930.

Spearman bases his theory upon the tetrad equation which is as follows:

$$r_{12}r_{34} - r_{14}r_{23} = 0$$

Spearman says,[2] "Whenever the tetrad equation holds throughout any table of correlations, and *only* when it does so, then every individual measurement of every ability (or of any other variable that enters into the table) can be divided into two independent parts which possess the following momentous properties. The one part has been called the 'general factor' and denoted by the letter '*g*'; it is so named because, although varying freely from individual to individual, it remains the same for any one individual in respect to all the correlated abilities. The second part has been called the 'specific factor' and denoted by the letter '*s*.' It not only varies from individual to individual, but even for any one individual from each ability to another. The proof of this all-important mathematical theorem has gradually evolved through successive stages of completeness, and may now be regarded as complete."

2. *The Tetrad Differences and Their Probable Error.*—The tetrad is the criterion of the Spearman theory. The tetrad differences are shown in Table II together with the probable errors.

TABLE II

TETRAD DIFFERENCES AND THEIR P.E.'S

Strengths						Jumps					
Regular			Ht. and Wt. partialed out			Regular			Ht. and Wt. partialed out		
t	Diff.	P.E.	t	Diff.	P.E.	t	Diff.	P.E.	t	Diff.	P.E.
1234	—.041	±.020	1234	—.026	±.012	1234	.039	±.024	1234	.039	±.024
1243	—.019	±.019	1243	.009	±.006	1243	.073	±.020	1243	.085	±.019
1343	.021	±.019	1343	.035	±.011	1343	.044	±.013	1343	.046	±.014

In the "strengths" it will be noted that the tetrad differences are small and the probable errors indicate that the differences are insignificant. When height and weight are eliminated the differences are smaller and also insignificant.

In the "jumps" the tetrad differences are also insignificant since five times the probable error well covers the difference.[3] Thus the tetrad criterion is satisfied and we may look for a common factor which we will call "*g*."

It is well to note that this purely mathematical method is used to determine the presence of some common factor "*g*" and some specific factors "*s*" if they exist. (It does not, however, give any hint as to what these factors are.)

[2] C. Spearman, *The Abilities of Man*, pp. 74-75. New York: Macmillan Co., 1927.
[3] *Ibid.*, pp. 140-141.

3. *Correlations with "G."*—Each event in each group is now correlated with "*g*" and the results are tabulated in Table III.

TABLE III

CORRELATIONS WITH "G"

Strengths			Jumps		
		(ht. and wt. out)			(ht. and wt. out)
Event	r_{ug}	$r_{ug.56}$	Event	r_{ug}	$r_{ug.56}$
Chin	.940	.281	Stand Broad	.660	.598
Dip	.884	.388	Run Broad	.693	.748
Sit up	.648	.459	St. Hop-Step	.740	.709
Shot	.577	.000	Run Hop-Step	.762	.749

4. *Weighting of the Events that Make Up the Pool.*—It will be noted that the events vary greatly in the amount of "*g*." The shot is very low, and when height and weight are eliminated it disappears in the pool. The "jumps," as might be expected, are more uniform.

TABLE IV

WEIGHTINGS OF THE EVENTS THAT MAKE UP THE POOL

Strengths			Jumps		
Events	r_{ug}	Weighting	Events	r_{ug}	Weighting
Chin	.940	7.535	St. Broad	.660	.793
Dip	.884	3.566	Run. Broad	.693	.923
Sit Up	.648	.724	St. Hop-Step	.740	1.212
Shot	.577	.499	Run. Hop-Step	.762	1.368
$r_{pg} = .962$			$r_{pg} = .901$		

Strengths (ht. and wt. out)			Jumps (ht. and wt. out)		
Events	r_{ug}	Weighting	Events	r_{ug}	Weighting
Chin	.281	.086	St. Broad	.598	.558
Dip	.388	.178	Run. Broad	.748	1.273
Sit Up	.459	.267	St. Hop-Step	.709	1.012
Shot	.000		Run. Hop-Step	.749	1.278
$r_{pg} = .589$			$r_{pg} = .901$		

5. *Correlations of the Weighted Pool with "G."*—It will be noted that (Table IV) by pooling the tests the correlation with "*g*" is increased very little over the highest one in the "strengths." To create the highest correlation for a pool one should select tests whose correlations with "*g*" are fairly equal. You will note a large increase in the "jumps."

The ultimate goal is to get a pooled test with a very high correlation with "*g*." Then, of course, the pool will actually measure the "*g*." By comparing the correlations of the pool with "*g*" when weight and height are partialed out we get a possible indication of the nature of "*g*." Evidently height and weight are of unequal importance to the "*g*" measured in each test.

6. *The Determination of "G" for an Individual from a Pool of Tests.*—Each score for each event must be changed to a standard score and then weighted according to Table IV, using the Means in Table V, by the following formula:

$$\frac{(\text{Raw Score} - \text{Mean Score})}{S.D.} \times \text{Weighting} = \text{Weighted "}g\text{" score.}$$

TABLE V

MEANS AND S. D. OF THE RAW SCORES

Strengths			Jumps		
Event	Mean	S.D.	Event	Mean	S.D.
Chin	149.36	15.80	St. Broad	7′7″	6.15″
Dip	168.05	20.16	Run. Broad.	13′8″	15.9″
Sit Up	188.00	23.7	St. Hop Step	21.24′	1.8′
Shot	28.94	4.34	Run. Hop Step	29.5′	2.32′

After we have weighted the different tests in the pool we can now determine the amount of "*g*" for each individual.

TABLE VI

CORRELATION OF "G" IN THE "STRENGTHS" WITH THE "G" IN THE "JUMPS"
(all values are in terms of standard scores)

Regular		Height and Weight Partialed Out	
Mean Strengths	—.3	Mean Strengths	.03
S. D. Strengths	12.70	S. D. Strengths	1.16
Mean Jumps	.00	Mean Jumps	.13
S. D. Jumps	4.98	S. D. Jumps	4.98
$r_{sj} = .456$		$r_{sj} = .417$	
$P.E._r = .0266$		$P.E._r = .0278$	

Now we can compare the two tests by correlating the "*g*" scores of the four hundred individuals. You will note in Table VI that the correlations are somewhat low. This would indicate that the two tests measure quite different general factors.

CONCLUSIONS

1. According to the tetrad criterion we may presume that the "strengths" have a common factor. When height and weight are partialed out the criterion is still satisfied. Likewise with the "jumps," al-

though the tetrad difference is larger, we may still, according to Spearman, assume a common factor to be present.

2. In correlating the different events with "*g*," we find that the events in the "strengths" vary greatly, while the correlations of events in the "jumps" are much more nearly equal. This conforms quite well with the general subjective evaluations of these tests.

3. When height and weight are partialed out both in the "strengths" and "jumps" we find interesting results. In the "strengths" we find the correlations greatly decreased, which may indicate that height and weight play a large part in the common factor of the "strengths." The correlation of the shot with "*g*" drops to nothing. The shot, apparently, has nothing in common with "*g*" found in the chin, dip, and sit-up but height and weight. Timing and coordination are great factors in successful shot-putting, while in the other events pure muscle strength plays the greater part. In the "jumps," with height and weight eliminated, we find very little difference, making it appear that the nature of the general factor in the "jumps" is very little concerned with height and weight. Thus it would seem that the general factor in the "jumps" and the "strengths" are quite different from each other.

4. The best pool of tests is made up of a larger number of tests than are given in this study. These tests should be fairly equal in their correlation with "*g*." Hence the best pool of tests for strength is the one where height and weight are not partialed out, for then we have four tests, and a higher pool correlation with "*g*" may be produced by correlating the "*g*" in the "strengths" with the "*g*" in the "jumps," when height and weight are *not partialed out*. This was true (.456 as compared with .417). Considering the *P. E.*, the difference is insignificant.

5. Thus we may conclude that there is a fairly low relationship between the common factor in the "strengths" and the common factor in the "jumps." However we must add that different pools of tests should be tried which undoubtedly would give us better measures of "*g*" in each group and then in turn a better study could be made of the relationships. We might conclude by saying that we feel the study was worth while if it will stimulate further interest in test evaluation in the field of physical education.

The Effect of Hip Elevation on Starting Time in the Sprint

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ONE OF the points of technique in the start of the sprint about which there are differences of opinion is the hip position which a sprinter should assume on the command "get set." By observing the start of a large number of sprinters, a wide variation in hip position was found. In discussing the question with a number of coaches, it was evident that they disagreed as to the best hip position for a sprinter to assume in the "set" position.

A survey of the literature yielded no reports except personal opinions based on subjective data.

In order to throw some light on the question of the way in which starting time is affected by the position of the hips at the start of a sprint, the investigation herein reported was carried out.

TECHNIQUE

Hip Elevation.—In order to measure hip elevation the apparatus shown in Fig. 1 was employed. It consists of a wood pointer (*B*) fastened to a ring stand near one end. A thumb screw holds the pointer firmly against a scale marked in degrees. The scale and pointer may be raised or lowered to meet the requirements of different sized men. The ring stand is placed near the sprinter's head when he is in the "set" position. The hip elevation is measured in degrees, by adjusting the pointer parallel to the trunk axis of the sprinter when he is in the "set" position. When the trunk was parallel with the track, the elevation of the hips was considered zero degrees. The position of the hips was measured as a positive angle when they were above the shoulders and as a negative angle when they were below.

Since it is generally agreed that a fast start in a sprint is conducive to a fast race, starting time was used in studying the effect of hip elevation.

Starting Time.—Starting time, in this investigation, is defined in accordance with the suggestion of Tuttle and Bresnahan as the interval elapsing between the pistol shot and the breaking of the contact with the track with the foot back.

The apparatus has been described in detail by Tuttle and Bresnahan.[1] Briefly, it consists of a sound key which starts a chronoscope when the pistol is fired, and a modified starting block which stops it the instant the foot back leaves the block. Starting time is read directly from the chronoscope dial in milliseconds.

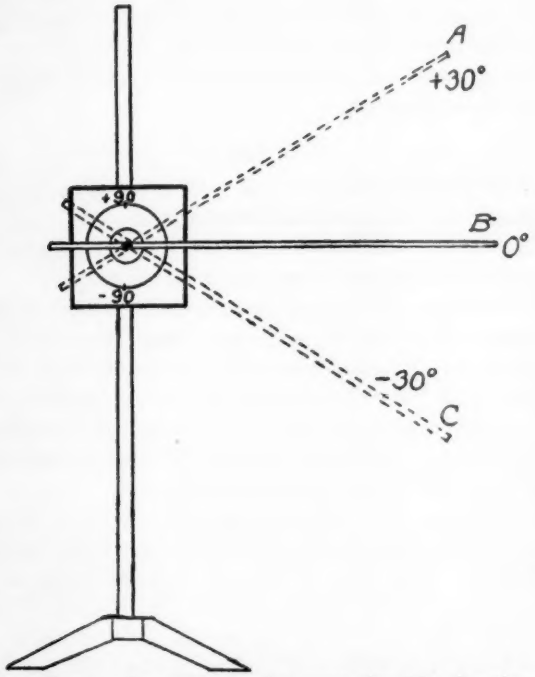

FIG. 1.—An apparatus for measuring hip elevation during the "set" position at the start of a sprint.

In order to study the effect of the angle of elevation of the hips on starting time, trained sprinters were employed as subjects. All sprinters assumed a bunch foot position as the type of start. Each sprinter was called to his mark, nothing having been said to him relative to the position of his hips. As soon as the command "get set" was given and he had assumed his natural position, the position of his hips was quickly measured by the apparatus previously described. During the course of the experiment, the sprinter was asked to take a position on the blocks with the hips higher than normal. After a few practice trials, his starting time was measured from this position. At some other time the sprinter was

[1] W. W. Tuttle and G. T. Bresnahan, "An Apparatus for Measuring Starting Time in Foot Races," *Research Quarterly*, IV: 2 (May, 1933), 110–116.

asked to take a "set" position in which his hips were kept lower than normal, and his starting time was again measured. The angle of the hips which was assumed was quickly measured in each case. The hip positions were alternated so that two starts in succession were never made with the same elevation.

The experiment was carried out on an indoor track constructed especially for investigations in the start of the sprint. All starting was done by an experienced starter under the direction of Coach George T. Bresnahan. At all times, conditions were maintained as nearly like those around the regular track as possible.

THE DATA

Twenty-four trained sprinters were used as subjects. Each man came to the laboratory on 3 different occasions, and started 7 times from each of 3 positions. Twenty-one starts were thus executed for each position, making a total of 502 starts for each angle of elevation.

Angle of Elevation.—Three angles of elevation were investigated, and were designated as low, normal, and high. When the subject came to his mark, the low angle was described to him as one in which the hips were to be maintained in the "set" position at a lower angle than was normally used by him. The high angle of elevation was arrived at through similar instruction. In the normal position nothing was said to the subject except that he was to use his usual start.

A summary of the data relative to hip elevation is shown in Table I. It is of interest to note that none of the subjects normally assumed a "set" position where the trunk was horizontal with the track, or where the hips were lower than the shoulders. For the great majority of the men the hips were 10 degrees or more higher than the shoulders. The data show also that when a sprinter voluntarily assumed a lower hip elevation than normal, the trunk was practically parallel with the track or else just slightly below the horizontal. However, when the instructions were to assume a high hip position, one was assumed where the hips were as much as 32 degrees higher than the shoulders. This seems to indicate that it is more natural to carry the hips high rather than low in the "set" position.

Starting Time from the Various Positions.—A summary of the data relative to the effect of the hip elevation on starting time is shown in Table II. The mean starting time from the low hip position is .3806 $\pm$ .0545 secs. From the natural starting position the mean time is .3109 $\pm$ .0545 secs., and from the position where the hips are higher than normal, the starting time is .2225 $\pm$ .0324 secs. On the basis of group means it is obvious that when the hips are elevated above the normal, the starting time is shortened, while it is increased when they are placed below normal. That the increase in starting time due to lowering the hips

TABLE I

THIS SUMMARY TABLE SHOWS THE MEAN HIP ELEVATION USED BY EACH SUBJECT IN EACH POSITION INVESTIGATED

Sub. No.	Angle of hip elevation		
	Low Angle	Normal Angle	High Angle
	degrees	degrees	degrees
1	—8	4	30
2	3	14	31
3	—3	7	31
4	2	15	32
5	—3	9	30
6	—1	11	25
7	1	11	22
8	—2	9	23
9	2	10	28
10	—1	9	21
11	1	12	27
12	—9	12	28
13	2	11	25
14	—5	6	25
15	—1	10	31
16	3	12	30
17	—2	6	24
18	—4	7	26
19	—5	12	29
20	—3	16	24
21	—2	7	22
22	—3	10	26
23	—3	13	30
24	1	12	26
Mean	—3	10	27

below normal is significant is shown by the fact that the difference between the starting time means from the normal position and from the lower position is 4.44 times the probable error of the difference. In the case of the difference between starting time with the normal hip elevation and in a position where the hips are elevated above normal, the difference between the means is 6.85 times the probable error of the difference. These facts eliminate any element of chance in the experiment and make the starting time differences highly significant.

The significance of the individual differences in starting time between the low and normal, and the normal and high hip positions is shown in Table III. In all cases except one, the differences are highly significant. In the case of subject 3, the starting time from a low hip position was equally as good as from the normal position. We have no explanation for this situation. However, when this subject raised his hips higher than normal in the "set" position, there was a perfect chance that his starting time was faster.

SUMMARY AND CONCLUSIONS

The part which hip elevation in the "set" position plays in the starting time of the sprint was investigated where the bunch start was used. Data were collected relative to the starting time from three hip positions, viz., the normal position, a position where the hips were lower than normal, and one where they were appreciably higher than normal. The following conclusions were drawn on the basis of the data obtained:

TABLE II

THIS IS A SUMMARY OF THE MEAN STARTING TIMES SECURED FROM TWENTY-FOUR TRAINED SPRINTERS, USING HIP ELEVATION AS INDICATED

Sub. No.	Low		Normal		High	
	Mean	P.E.	Mean	P.E.	Mean	P.E.
1	.4861	.0450	.4447	.0380	.3081	.0594
2	.2711	.0834	.1777	.0474	.1059	.0318
3	.2743	.0710	.2740	.0830	.1755	.0306
4	.4359	.0765	.3525	.0509	.3138	.0360
5	.4537	.0311	.3833	.0609	.2594	.0606
6	.4043	.0356	.3192	.0439	.2163	.0356
7	.2896	.0420	.2380	.0299	.1896	.0325
8	.4316	.0487	.3979	.0194	.2083	.0371
9	.4697	.0390	.3955	.0479	.2745	.0567
10	.3857	.0391	.3025	.0576	.2152	.0418
11	.4682	.0263	.3122	.0415	.2094	.0248
12	.4038	.0412	.3292	.0383	.2044	.0504
13	.4318	.0668	.3312	.0643	.2384	.0464
14	.2330	.0282	.2099	.0242	.1685	.0282
15	.3057	.0373	.2622	.0378	.2278	.0268
16	.4460	.0558	.3610	.0382	.2013	.0467
17	.3360	.0482	.2868	.0391	.2474	.0277
18	.4198	.0472	.3739	.0337	.2809	.0569
19	.4385	.0525	.3617	.0516	.2242	.0548
20	.5254	.0244	.4258	.0341	.3117	.0350
21	.3267	.0360	.2600	.0295	.2050	.0170
22	.2668	.0204	.2183	.0129	.1819	.0380
23	.2692	.0177	.2014	.0283	.1760	.0250
24	.3628	.0505	.2433	.0313	.1975	.0341
A.M.	.3806		.3109		.2225	
S.D.	.0808		.0808		.0480	

1. The hip position which the sprinters naturally assumed varied from 4 to 16 degrees, with a mean of 10 degrees above the shoulders, elevation being measured in terms of the deviation of the trunk axis from the horizontal. In no case did a sprinter assume a position where his trunk was parallel with the track or lower than the shoulders.

2. When the angle of elevation of the hips was lessened, so as to approach a trunk position paralleling the track, starting time was significantly increased.

3. When the angle of elevation of the hips was materially increased

from the normal position of 10 degrees, the starting time was significantly shortened.

4. On the basis of the data presented in this investigation, it is evident that a high hip position in the bunch start yields the shortest starting time.

TABLE III

THIS TABLE SHOWS THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEAN STARTING TIME FROM EACH HIP ELEVATION FOR EACH SUBJECT

Sub. No.	Low - Normal			Low - High			Normal - High		
	Diff.	P.E.diff.	Diff. / P.E.diff.	Diff.	P.E.diff.	Diff. / P.E.diff.	Diff.	P.E.diff.	Diff. / P.E.diff.
1	.0414	.0125	3.31	.1780	.0211	8.44	.1366	.0209	6.53
2	.0934	.0209	4.47	.1652	.0194	8.52	.0718	.0124	5.79
3	.0003	.0238	.01	.0985	.0169	5.83	.0985	.0193	5.10
4	.0834	.0205	4.07	.1221	.0185	6.60	.0387	.0136	2.85
5	.0704	.0149	4.72	.1943	.0148	13.04	.1239	.0187	6.63
6	.0851	.0124	6.86	.1880	.0110	17.09	.1029	.0124	8.30
7	.0516	.0112	4.61	.1000	.0117	8.55	.0484	.0096	5.04
8	.0337	.0114	2.96	.2233	.0115	19.42	.1896	.0091	20.84
9	.0742	.0134	5.54	.1952	.0150	13.01	.1210	.0161	7.52
10	.0832	.0152	5.47	.1705	.0125	13.64	.0873	.0155	5.63
11	.1560	.0107	14.58	.2588	.0078	33.18	.1028	.0105	9.79
12	.0746	.0123	6.07	.1994	.0142	14.04	.1248	.0139	8.98
13	.1006	.0104	9.67	.1934	.0177	10.92	.0928	.0172	5.40
14	.0231	.0081	2.85	.0645	.0088	7.33	.0414	.0081	5.11
15	.0435	.0115	3.78	.0779	.0099	7.87	.0344	.0105	3.28
16	.0850	.0147	5.78	.2447	.0159	15.39	.1597	.0131	12.19
17	.0495	.0135	3.67	.0886	.0121	7.32	.0394	.0104	3.79
18	.0459	.0127	3.61	.1389	.0161	8.63	.0930	.0144	6.46
19	.0768	.0161	4.77	.2039	.0165	12.36	.1271	.0164	7.75
20	.0996	.0091	10.95	.2137	.0093	22.30	.1141	.0106	10.76
21	.0667	.0103	6.48	.1217	.0087	13.99	.0550	.0074	7.43
22	.0485	.0053	9.15	.0849	.0094	9.03	.0364	.0088	4.14
23	.0678	.0073	9.29	.0932	.0067	13.91	.0254	.0083	3.06
24	.1195	.0129	9.26	.1653	.0133	12.43	.0458	.0105	4.36

A Study of Hammer Velocity and the Physical Factors Involved in Hammer Throwing

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IN ORDER to meet the needs of those who are interested in the results of this research rather than the technical approach to the problem, a summary of the results of the investigation is presented at the beginning of this report. Following this the procedure in securing the data upon which the conclusions are based, together with an analysis of the data, is presented. Part 1 deals with the velocity of the hammer and Part 2 deals with the physical factors involved in the throw.

SUMMARY AND CONCLUSIONS

I. *Velocity of the Hammer.*—By means of a motion-picture technique thirteen hammer throws, including performances by Hawkins and Ketz of Michigan, Gwinn of Pittsburgh, and Black of Maine, are analyzed from the standpoint of hammer velocity. On the basis of this analysis the following conclusions are drawn:

1. Whenever the right foot was removed from the ground during a turn, there was a loss in the hammer speed.

2. Whenever the right foot was on the ground during a turn, there was a gain in hammer velocity.

3. With the exception of the final pull, a loss in velocity was usually found when the hammer was moving upward during the turns.

4. There was a gain in all cases during the downward swing of the hammer.

5. There was a gain in velocity in every case during the final pull.

6. There were large gains in velocity whenever both feet were on the ground throughout the turns and the final pull.

7. It was found that three types of turns were used by the throwers observed: (*a*) the toe turn or pivot plus a hop; (*b*) the heel-toe turn; and (*c*) a combination of both, using the toe for the first turn and a heel-toe turn for the remaining rotations.

In all toe turns, the right foot was in the air as long as or longer than it was on the ground. In all the heel-toe turns, the right foot was on the ground longer than it was in the air. (Recall that the right foot position governs the velocity gains.) The evidence appears to show rather distinctly that the heel-toe turn is the best.

The thrower known to be the best performer used the heel-toe turn for all three body rotations. During the turn, he did not appear to have both feet off the ground at the same time.

II. *Physical Factors Involved in the Throw.*—In order to study the physical factors involved in hammer throwing, data were gathered from 10 consecutive throws made by the same athlete in one evening. His throws averaged 143 feet. On the basis of these data the following conclusions are drawn:

1. The centrifugal force developed had a maximum of 462 pounds.
2. The average kinetic energy developed was 1,155 foot pounds.
3. The hammer was in the air 2.79 seconds.
4. The time used in making the two turns averaged 1.35 seconds.
5. The average total time for energy development was 5.43 seconds.
6. The average horizontal velocity of the hammer was 51.25 feet per second.
7. The average initial velocity of the hammer was 67.97 feet per second.
8. The average angle of the hammer release was found to be 41 degrees.

For those interested in the technical approach to the problem of hammer throwing the details of the experiment are presented.

1. THE VELOCITY OF THE HAMMER

The analysis of the velocity of the hammer was based on 450 feet of motion-picture film. This film was made available through the courtesy of Thomson of the U. S. Naval Academy, Bresnahan of Iowa, and Jones of Wisconsin. The films were taken at the Drake Relays of 1929-30, the Western Intercollegiate Conference Meet of 1928, the National Collegiate Association Meets of 1926–27–28, an I.C.A.A.A.A. Meet, and the Junior A.A.U. Meet of 1930. The collection contained the performances of all the middle-west champions and some of the leading eastern throwers. The immediate problem was to find some suitable method for obtaining reliable information regarding hammer velocity from the film.

Method.—In the beginning, two assumptions were made: (1) that the path of the hammer is a circle or nearly so, and (2) that the time interval between pictures at full speed of the camera is constant.

In support of the first assumption a figure of a hammer path tracing will be used. Figure 1 shows the path of a hammer as it looks when photographed by a camera in front of the thrower. (Each number represents one picture.) To the right of this is a tracing of the hammer path from pictures one to twenty. This tracing is fitted with a dotted ellipse which shows how exactly this path corresponds to an ellipse.[1]

[1] An ellipse is the shape any circle will take when viewed from any angle except the vertical axis.

The correctness of the first assumption is amply supported by the solution of an actual problem in rotary motion based on data taken from

FIG. 1.—This shows the plot of a two-turn throw. 22*A* is the start of the first turn, 35*B* is the start of the second turn, and 44*C* is the start of the first pull. Each number represents the hammer position at the time that the corresponding picture was shown. By following the numbers from 1 to 48 we have the path taken by the hammer head from the preliminary swing before the start of the first turn until the hammer was released.

the pictures. Let us assume that the radius of the circular path of the hammer is 5 feet. This means that 1 foot is added to the hammer length, thus placing the elbow at about the center of rotation. From data collected in a previous study,[2] it was found that a thrower makes 2 turns in 24 pictures taken at the rate of 16 frames per second. The average speed of rotation is one complete turn in three-fourths of a second. Now by means of the formula $F_c = 4\pi^2 rmn^2$,[3] the centrifugal force is computed as 175.6 lbs. It is obvious that this force is constant as long as the radius and the number of turns are constant.

Now if the hammer does not move in a circle but moves with a radius fluctuation of only six inches the situation becomes involved. Figure 2 shows the path as it would be if a true circle of five feet were followed, and as it would be if it followed an elliptical path.

Under these new conditions, the most favorable assumption possible for the fluctuation of three inches on either side of the true circle is a

[2] V. W. Lapp, A Motion Picture Analysis of the Technique of the Hammer Throw. M.A. Thesis. On file in State University of Iowa Library, Iowa City, Iowa.

[3] In the formula F_c is centrifugal force; r is 5 feet; m is mass which is 16/32 slugs; and n is 4/3 revolutions per sec. (Equation 1).

simple harmonic motion having an amplitude of six inches impressed on the original uniformly rotating body. It must be understood that this simple harmonic motion has a frequency of twice that of the rotating

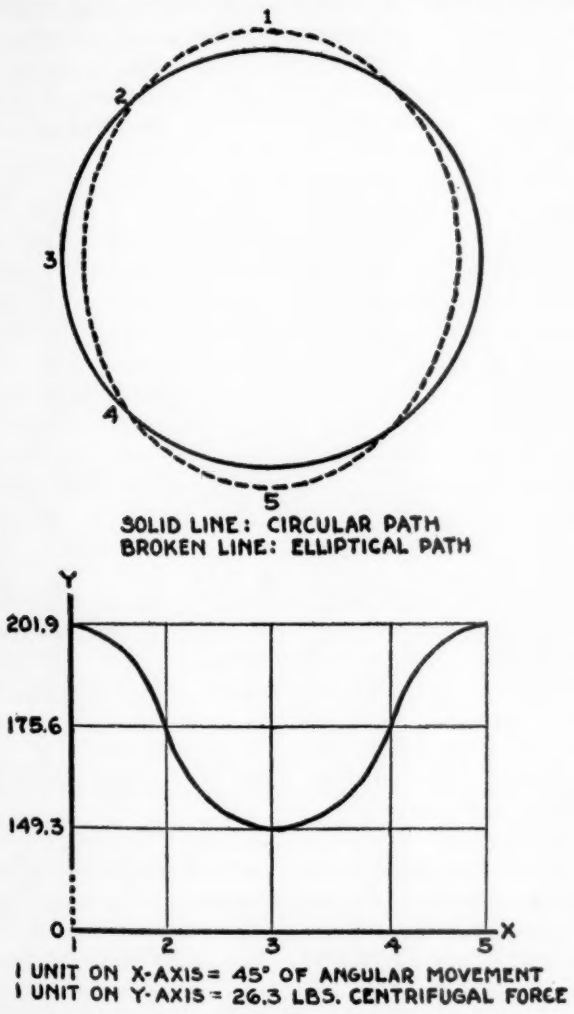

FIG. 2.—This is a simple harmonic motion illustrated.

body. A simple harmonic motion may be analyzed by a circle of reference with a diameter of six inches. One-half of this diameter is the maximum displacement of the hammer from the true circle.

It can readily be shown[4] that a body with 0.5 slug mass executing

[4] This figure is arrived at by equation 1 by substituting 3 inches for r, 8/3 for n, where the remainder of the formula is unchanged.

simple harmonic motion under the above conditions has forces acting on it which vary along a sine curve with a maximum force of 35.1 lbs.

Due to the change in radius, the centrifugal force varies from 175.6 lbs. When the hammer is at position 1 on Figure 2, the centrifugal force is smallest, due to the maximum radius, and the total force acting on the wire handle is $175.6 - 8.8 + 35.1 = 201.9$ lbs. where the 8.8 is the decrease due to change in radius. At point 2 it becomes 175.6 lbs. and at point 3 the force is increased by 8.8 lbs., due to shortened radius, and decreased by 35.1 lbs., due to the impressed simple harmonic motion as the direction of simple harmonic motion reverses, making a total force on the man of 149.3 lbs.

Thus we have a force of 26.3 lbs. (35.1 lbs. — 8.8) changing its direction of pull causing a fluctuation of 26.3 lbs. 4 times each revolution of the hammer. A force curve of this type for one-half of a hammer revolution is shown graphically on the bottom of Figure 2.

A force of this type would make it nearly impossible for a thrower to remain in a state of equilibrium. This type of variation in force is present for any fluctuation from a normal circle. With a fluctuation larger than six inches this force would be proportionately larger. Therefore, a variation from the normal circle, if any, must be small compared to the variation of 5 per cent computed in the above problem which makes the technique of this study easily effective.

The second assumption is supported by an investigation by Irwin.[5] He showed that with a spring camera the maximum variation in time between pictures was 3 per cent, with an average variation of 2 per cent.

Any ellipse may have a circle of reference fitted to it and may thus be analyzed. By finding the circles which will fit the elliptic path of the hammer one is in position to break down this path into velocity differences between the equally timed picture spaces.

The problem of finding these circles of reference was attacked with the apparatus in Figure 3.

The first step was the reproducing of the hammer path (Figure 3). This was done by placing a sheet of heavy white paper (16″x 20″) as a screen for the projector. (The projector was fixed at a constant distance from the screen and arranged so that it could be elevated or moved sideward slightly. This was to permit a slight adjustment of the picture on the screen to counteract any movement which might have been made by the photographer.) The screen was also in a fixed position at right angles to the line of projection. The pictures were shown on the screen as in Figure 3, one at a time, and numbered consecutively. The hammer was moving so fast that it made a streak of light on the film. A line was drawn on the side of the hammer streak next to the thrower of which the middle was noted by a distinctive mark.

[5] O. C. Irwin, Iowa Child Welfare Research Station, State University of Iowa. Personal communication.

The next step was the fitting of the circle to the elliptic path. This was done by removing the film from the projector and putting a diaphragm over the lens which permitted only a small amount of the total light to pass through its punctured center. This caused any object between the projector and screen to give a sharp shadow. The round disk shown in Figure 3 was then adjusted until its shadow just fitted the ellipse to be analyzed. By moving a pencil or a sharp pointed object on the edge of the disk its shadow fell on the hammer positions on the

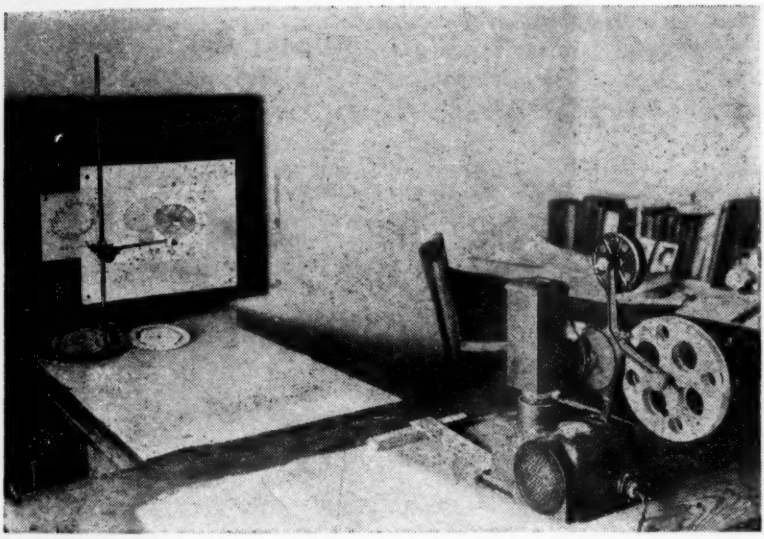

FIG. 3.—This figure shows the apparatus for analyzing the motion picture. It consists of (1) the projector in its cut-out-rest at the back and the slide elevator shown in front. (2) The three round disks used, showing the smaller one mounted in front of the base of the stand. On the screen is fixed the hammer plot shown in Figure 1. The projector is running and the reader may note how exactly the shadow of the disk fits the ellipse on the screen. The disk shown has a 5-degree scale.

screen. The difference in these positions was read from the circular disk which was calibrated in 5-degree intervals. By adjusting the pencil shadow, the difference was read to 1 degree.

In order to counteract slight differences in judgment as to the location of the center of the hammer streak, these differences as measured in degrees were averaged so that each difference is a mean of the reading of itself with the reading before and after it (rolling average method). After this smoothing process, the differences were plotted as shown in Figures 4, 5, and 6. On the x-axis the time intervals are plotted by numbering each of the squares with the consecutive picture numbers. The y-axis was the angular velocity of the hammer head plotted in

velocity differences between the pictures. Thus when the head is going faster the height is greater, and when the slope is steepest the acceleration is the greatest. Also below the x-axis the picture numbers[6] where the feet moved and the turns started are marked with letters. The typical curves[7] of two, three, and four turn throwers are shown in Fgures 4, 5, and 6.

Because of the nature of the velocity technique, only pictures which were taken from the front were used. This was necessary since the plot of a throw taken from the side takes the shape of a corkscrew when viewed from the side, giving sharp angles which could not be accurately read.

The subjects used for this study are listed and classified below, the classification in feet being based on the distances they had thrown consistently during the current year:

Throwers No.	*Turns used*	*Known achievements*	*Distance class*
1	2	Place winner N.C.A.A.	135′
2	2	Place winner N.C.A.A.	135′
3	2	Big Ten and N.C.A.A. & Penn Relay Champion	150′
4	2	Place winner I.A.A.U.	150′
5	2	Place winner I.A.A.U.	150′
6	2	Eastern Thrower	No data
7	3	Big Ten & N.C.A.A. Champion	160′
8	3	Place winner I.A.A.U.	150′
9	3	Place winner I.A.A.U.	150′
10	3	Place winner I.A.A.U., N.C.A.A. & Big Ten	145′
11	3	Penn Relay Champion	160′
12	4	N.C.A.A. and Drake Relay Champion	160′

2. PHYSICAL FACTORS IN HAMMER THROWING

Data were gathered from ten consecutive throws made by the same athlete in one evening. The times were taken by means of tenth-second stop watches. The distances were measured by the use of a two-hundred-foot steel tape and were taken from the circle to the nearest point where the hammer head struck the ground. These data are shown in Table I.

The Speed of the Hammer on Its Release.—Initial velocity may be determined by the use of a formula worked out by Whitney,[8] which rests on the assumption of negligible air resistance. This assumption seems valid because of the weight, small size, and low velocity of the hammer.

In order to find this velocity, two measurements are necessary: (1) the time of hammer flight, and (2) the distance of the throw.

To be accurate, the time of flight ought to be measured from the lowest point of the hammer just before its release until it lands. The distance should be measured from the same points used in timing.

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[6] The picture numbers were noted as the original hammer path was being plotted.

[7] These curves shown here have been smoothed a second time by inspection after the plotting.

[8] John D. Whitney, Professor of Physics, St. Louis Municipal University, St. Louis, Missouri. Personal communication.

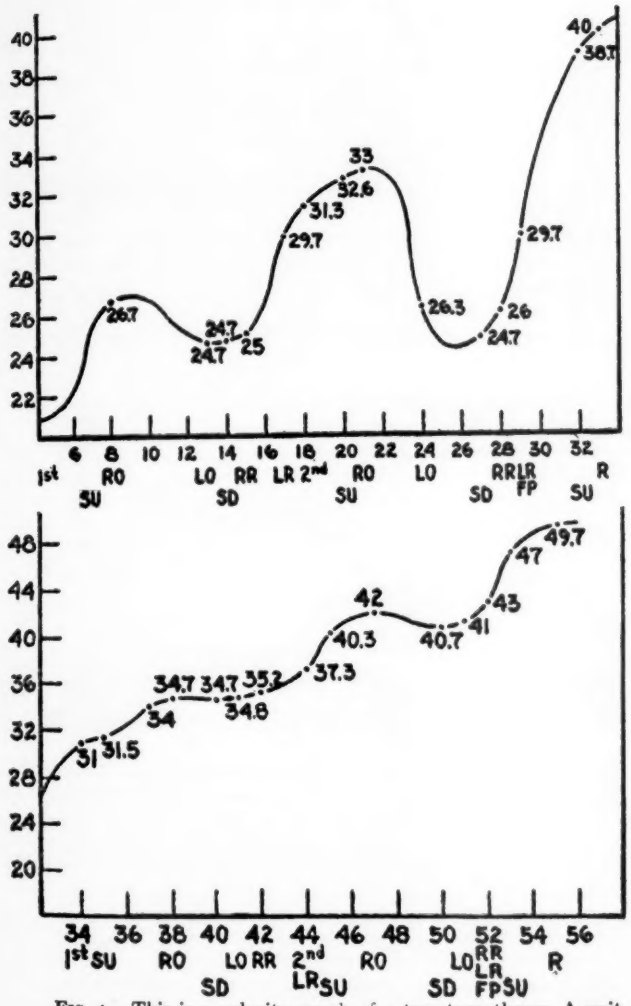

FIG. 4.—This is a velocity graph of a two-turn throw. A unit on the *Y*-axis of the upper picture is twice as long as a unit on the *Y*-axis on the lower picture. These throws cannot be compared in velocity as they were taken with different cameras at slightly different speeds. Note the loss on the second turn in the upper picture. The thrower would have gained about as much if he had put his final pull on the end of his first turn.

For the sample graphs standard abbreviations are used as follows:

X-axis—Time intervals between pictures.

Y-axis—Angular velocity difference between pictures as read from the hammer path, a sample of which is shown in Picture 1. 1st, 2nd, 3rd, and 4th indicate the start of the turn by the same numbers.

FP—Start of final pull.
RO—Right foot left the ground.
RR—Right foot returned to the ground.
LO—Left foot left the ground.
LR—Left foot returned to the ground.
SD—Hammer path starts downward.
SU—Hammer path starts upward.
R—Near the end of X-axis is the last picture in which the hammer was in the hands.

Numbers on the curve represent the angular velocity at the point to which the letters directly below them refer. The scale is shown in the upper right hand corner of each group.

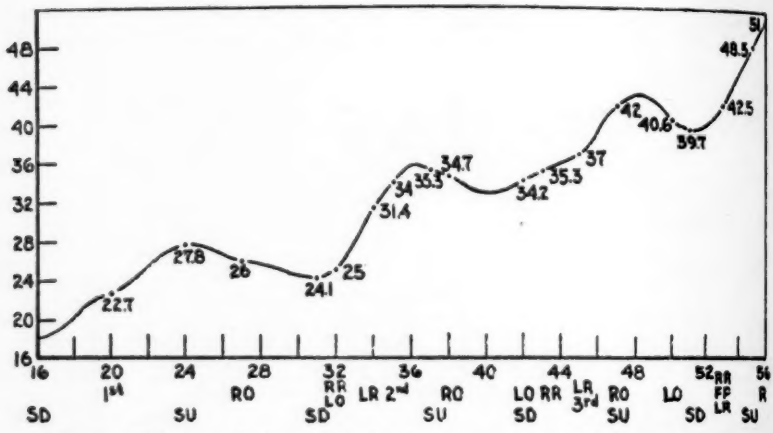

FIG. 5.—This is a velocity graph of a three-turn throw. This three-turn thrower (Ketz of Michigan) used the toe-jump turn. Notice how well this curve brings out the losses in velocity while the right foot is off the ground. The gains in velocity during the downswings of the hammer show in all the graphs while the losses are apparent in all the swings upward except the last one during the final pull.

In the computation of the data sheets, the point of hammer release and edge of circle were used in measuring time and distance of flight. The errors involved are very slight and tend to cancel each other. By substituting data from Table I in formula 2,[9] $V_0 = \sqrt{(\frac{S}{T})^2 + (16T)^2}$ the initial velocity of the hammer is found.

The initial velocity was found to vary from 69.8 feet per second to 65.7 feet per second. An average of 67.97 feet per second was found for the total ten throws.

The Angle of the Hammer Release.—In order to find the angle of release, we have only to use formula 2 and the data in problem one together with a table of trigonometric functions as follows:

[9] In formula 2, V_0 = initial velocity; T = time of flight; S = distance of the throw and $S/T = Vh$ which is horizontal velocity.

$$\text{Cos } A = \frac{Vh}{V_o} = \frac{Vh}{\sqrt{(Vh)^2 + (16T)^2}} = \frac{\frac{S}{T}}{\sqrt{(\frac{S}{T})^2 + (16T)^2}}$$

All notations are the same as for problem one.

The data show the angles of release to vary from 39 degrees to 43 degrees with an average of 41 degrees 3 minutes. An empirical determination would be the only way to actually find the best angle.

The Centrifugal Force Developed.—This force is calculated by formula 3 [10] as follows: $F = \frac{W V^2}{G R}$

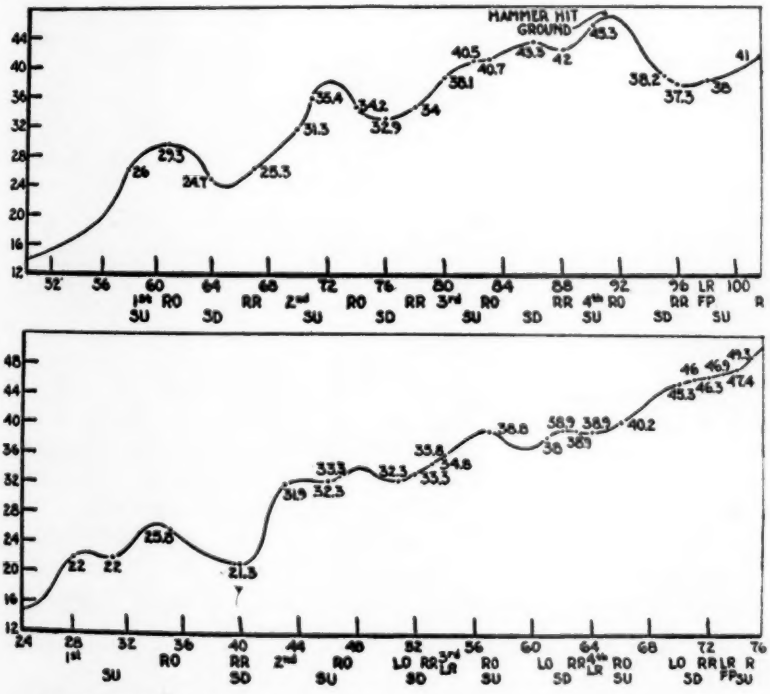

FIG. 6.—This is a velocity graph of a four-turn throw. This picture shows two throws by the same athlete (Gwinn of Pittsburg). Note the continual rise starting on the *SD* just before the second turn. In the upper picture a sharp fall in velocity is noted above picture 92. On looking for the cause of this drop, it was found that the hammer had struck the ground at the start of the fourth turn. (Notice how well this analytical method detected the drop in velocity.) The velocity on these throws may be compared, as they were taken with the same camera set for the same speed.

[10] In formula 3, F is the centrifugal force in pounds; W is the weight in pounds; V is initial velocity in ft./sec.; G is force of gravity (32 lbs./sec.); and R is the radius of rotation.

TABLE I

THIS TABLE SHOWS THE DATA COLLECTED RELATIVE TO THE PHYSICAL FACTORS INVOLVED IN THE HAMMER THROW *

	A	B	C	D	E	F	G
Throw No.	Time of flight	Time of turns	Distance of throw	Total time energy development	Horizontal velocity $\frac{S}{T}$ ft./sec.	Initial velocity (ft./sec.)	Angle of release
	sec.	sec.		sec.			
1	2.8	1.3	138′ 3″	6.8	49.4	66.7	42
2	2.8	1.5	134′ 8″	4.5	48.1	65.7	43
3	2.9	1.5	143′ 7″	4.6	49.5	67.9	43
4	2.8	1.3	147′ 10″	5.5	52.8	69.2	40
5	2.7	1.3	140′ 11″	5.5	52.2	67.8	40
6	2.8	1.3	148′ 10″	5.8	53.1	69.5	40
7	2.8	1.4	142′ 3″	5.5	50.8	68.6	42
8	2.7	1.3	143′ 9″	5.5	53.6	68.8	39
9	2.8	1.2	149′ 10″	5.1	53.5	69.8	40
10	2.8	1.4	142′ 3″	5.5	50.8	68.1	42
Ave.	2.79	1.35	143.01	5.43	51.25	67.97	41

* Columns A, B, C, and D are the result of direct measurement. Columns E, F, and G are computed from the values given in A and C. In calculations, all values were rounded to one decimal place and the angle measurement to the nearest degree, as more accuracy was not warranted by stop-watch timing.

The radius is assumed to be 5 feet. This is probably a very fair estimate for most throwers. Substituting the data from Table I in the formula, $F = \frac{16\ (67.97)^2}{32 \times 5} = 462$ pounds.

This figure seems to be large but it should be remembered that a counteracting force is developed by the body weight rotating at the same time. The arms must, however, stand a very large pull due to these forces. Any hammer thrower will testify to the size of this force by its action when he is caught off balance. This force is a maximum as it is computed from the velocity at the time of the hammer release.

The Kinetic Energy Developed.—Using the formula 4 [11] and substituting data from Table I the kinetic energy developed is found as follows: $K.E. = \frac{W V^2}{64}$. $K.E. = \frac{16 \times (67.97)^2}{64} = 1155$ foot pounds.

In throwing the hammer ten times, 11,550 foot pounds of energy was developed in a total time of 54.3 seconds.[12] This is more than equal to the work necessary to lift a ton of coal 5 feet.

[11] In formula 4, W = weight in pounds and V the initial velocity in ft./sec.

[12] The total time of energy development for each throw was taken from the time the hammer was lifted off the ground until it was released.

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